

**AN INVESTIGATION INTO
AIRCRAFT AVAILABILITY**

THESIS

Michael S. Kapitzke, Captain, USAF

AFIT/GSM/LAL/95S-4

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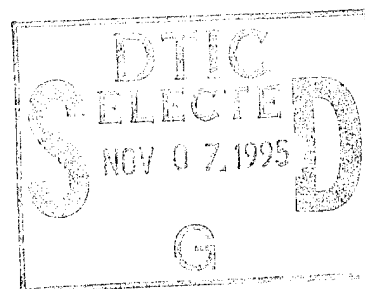
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AN INVESTIGATION INTO AIRCRAFT AVAILABILITY

THESIS

Presented to the Faculty of the Graduate School of Logistics and

Acquisition Management

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirement for the Degree of

Master of Science in Systems Management

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Preface

This study looked at the effect that the variability of input distributions has on the value of aircraft availability. To do this, a simulation model was developed which simulated the reparable item pipelines for 15 different items. This model provided the ability to change the variance of the input distributions and test the effect of this variance change on aircraft availability.

A search of the historic literature showed that four different variables are typically used in expected value models which are currently being used in the Air Force. Of those, under the assumption of lean logistics in the Air Force, only the depot repair time of the item and the failure/demand rate of the item were now used and thus, those variables were investigated. Also, with the current Air Force method of calculating failure/demand rate from the flying hours of the aircraft, a low flying hour program, hence a low failure/demand rate, and a high flying hour program, or a high failure/demand rate, were evaluated.

This study would not have been possible without the help of many people. First, I would like to thank my advisors Dr. Guide and Maj. Kraus for their support when I needed it and their “bludgeoning” when I required it. I would also like to thank Bill Morgan of AFMC/XPS for his work and time spent on the Air Force’s Aircraft Availability Model used in the validation of the simulation models. Next, I would like to thank my classmates; Kevin, Crash, Indy, Todd, Marie, Miro and Smitty, for their help and encouragement through the “fuzzy” classes. Finally, I would like to thank my wife Sherry for her love and continued support and my children; Kayla, Kelsey, and Kristopher, for their smiling faces and for being the reason I went to school.

Michael S. Kapitzke

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Abstract

The Air Force currently uses an expected value model in the Aircraft Availability Model (AAM) to calculate aircraft availability. However, even with the application of Lean Logistics, the failure/demand rate and the depot repair time are not fixed and the mean value is still used in the model. This research looks at the effect of the magnitude of the variance of the distributions of failure/demand rate and depot repair time. Also, this research evaluates the effect of variable mean failure/demand rates on the variability of aircraft availability.

A simulation model was developed which applied the variable failure/demand rates and depot repair times. Aircraft availabilities were calculated and the variances of the aircraft availabilities were computed. From this an ANOVA and paired t-tests were performed on the mean variances to test if the parameters significantly effected the variance of aircraft availability. From these tests, it was found that failure/demand rate variance and the failure/demand rate significantly effected the variance of aircraft availability with possible aircraft availabilities being $\pm 10\%$ in some cases.

Because the AAM generates an expected value, decisions made in the field based on meeting or not meeting that value should be examined carefully to ensure that the difference is not due merely to random effects in the system. Also, in any expected value model, variances in the input distributions will lead to a range of actual values. As before, each decision which is based on meeting a given level generated by an expected value model should be thoroughly examined to ensure that this random effect is not overlooked.

AN INVESTIGATION INTO AIRCRAFT AVAILABILITY

I. Background

Introduction

Aircraft availability models have been developed to predict how many aircraft will be available for operation at a given time. These models base their calculations on the availability of reparable parts for which demand is forecasted, and the availability rate is the percentage of aircraft with a complete set of these reparable parts (Rexroad, 1992:1). In recent years the Department of Defense (DOD) budget has been shrinking and aircraft availability has become an ever increasing issue of concern.

As a result, the DOD has been forced to find ways to do more with less. In the logistics management arena, the DOD established the Joint Logistics System Center (JLSC). The JLSC's main mission is to evaluate and select logistics sub-systems from each service's logistics system to produce a standard DOD logistic system appropriate to the Air Force, Navy, Army, and the Defense Logistics Agency (DLA) (Klugh, 1994). The difficulty lies in determining which sub-systems from the individual services can be taken and incorporated into one logistics system. This task is particularly difficult when each service has developed different approaches for similar sub-systems (Dussault, 1995: 1-2).

In 1992 the JLSC granted the Air Force authority to continue using the existing Aircraft Availability Model (AAM) for predicting aircraft availability and to aid in spares

provisioning (Klugh, 1994). This decision brought out concerns in the implementation of the AAM.

There are many pieces of information which are used for the calculation of aircraft availability. Of those pieces, there are four variables used which are mean values. They are: the base time to repair, the depot time to repair, the order and ship time, and the failure/demand rate of the component. Because the AAM uses the mean values of these variables, the variation in these values is assumed to be known and adequately accounted for in the design of the model. Unfortunately, even in the steady state world of peacetime flying, this assumption is not supported by any relevant data (Crawford, 1988: v).

Other than violating the assumptions of the model, the demand rate variability would not be so important if the numbers of units in repair were constant at an acceptable level. Unfortunately, the variation in the length of time parts are in repair is even greater than that of the demand rate (Crawford, 1988: vi). Thus, it is this variation in these values that has given rise to the question of robustness of aircraft availability predictions.

Purpose of the Study

The purpose of this study is to investigate the effect of the variance in input distributions on predicted aircraft availability. This research will evaluate the robustness of predicted aircraft availability through a simulation of the reparable item pipelines of a system using known means and theoretical distributions for input variables.

Specific Problem

Are there significant effects on expected aircraft availability due to variability in the reparable components' input distributions? In order to answer this question, this research question is broken down into investigative questions which focus on individual variables.

Investigative Questions

1. Does the variance of the distribution of the number of failures/demands have a significant effect on the variability of aircraft availability?
2. Does the magnitude of mean number of failures/demands have a significant effect on the variability of aircraft availability?
3. Does the variance of the distribution of the depot repair times of the components have a significant effect on the variability of aircraft availability?
4. How much variation in aircraft availability results from the different combinations of the input parameters?

Research Approach

The research approach to be used will first review the historical data of depot repair times and failure rates of individual components. Using the mean values for these components, distributions will be placed on the parameters, and a simulation model will then be constructed and used to evaluate aircraft availability to answer the research questions.

Scope and Limitations

This research has the same limits placed on it as those placed on the AAM. The AAM does not consider on-aircraft maintenance, scheduled or unscheduled, or shortages of consumables. Also, the AAM does not consider maintenance actions that consolidate reparable item shortages on aircraft (cannibalization) (Rexroad, 1992:2). Because these limitations are placed on the AAM, the simulation model was designed to adhere to these limitations also. This research is limited to the somewhat static environment of peacetime flying and thus, this effort will not consider aircraft availability during either a dynamic wartime environment or a pre-wartime build-up environment.

Summary

Next, Chapter II will review the mathematical foundations behind repairable inventory theory and the AAM. Following this review will be a discussion of the input parameters for the calculation of aircraft availability. Chapter III will then describe the methodological approach to be used to answer the research questions. Chapter IV will present the results of the simulations and a discussion of the data followed by conclusions of the research in Chapter V.

II. Literature Review

Overview

Aircraft availability models have been developed to help predict how many aircraft will be available for operation at a given time. Aircraft availability models base their calculations on the availability of reparable parts for which demand is forecasted, and the availability rate is the percentage of aircraft with a complete set of these reparable parts (Rexroad, 1992:1). If enough reparable parts are purchased for the repair pipeline, the aircraft availability would be near 100%, and the supply system would stock enough of these parts so that the Air Force would never have to purchase more. Unfortunately, the cost of purchasing enough parts would be astronomical, and the DOD does not have an endless supply of money. Since the DOD cannot purchase all these parts, it must rely on the forecasting and predicting models to help decide which and how many parts to purchase. The Air Force currently uses the AAM to perform this task. The AAM is an expected value model which computes aircraft availability using mean values and does not compute the variance of the distribution of aircraft availability.

To better understand aircraft availability and the AAM, this review will begin with a discussion of the foundations behind reparable inventory modeling, the AAM and its assumptions. Following this, the review will present the main calculations of the AAM and then present the input variables and their significance in the calculation of aircraft availability.

Foundations In Repairable Inventory Modeling

(S-1,S) Inventory Policy. The theory of (s-1,s) inventory is the foundation for reparable parts management (Klinger, 1994:9). This (s-1,s) inventory theory is based on a simple one-for-one ordering system: when a part breaks, a replacement part is ordered.

This order for a new part may be filled by either the base supply or the depot supply. If no spares are available at the base supply, the customer must then wait for either a part from depot supply or from base repair (Nahmias, 1981:254).

The performance of the inventory system is determined by the amount of spare stock, s , available in the base supply system (Feeney and Sherbrooke, 1966:391). This spare stock consists of three categories. The first category is the amount of stock on hand in the supply system. The second category is the amount of stock due in to supply. The last category is the amount of stock that has been backordered. The spare stock, s , can then be defined as the stock on hand plus stock due in minus backorders (Feeney and Sherbrooke, 1966:392). Thus, when stock is demanded, the inventory falls below s (at least to $s-1$). In order to return inventory to s , a backorder is placed for an equal amount of stock that has been demanded. So, if backorders exist, net inventory, which is stock on hand plus stock due in, may become negative (Nahmias, 1981:254).

Poisson Processes. Poisson processes are used because they “closely approximate real-world arrival processes” (Crawford, 1981:1). An arrival process is explained as, “some group of entities (people, aircraft, etc.), each of which may give rise to some event of interest (make a telephone call, have a radio failure, etc.) in each time interval” (Crawford, 1981:10). Suppose a random variable $x(i)$ is associated with each entity, and $x(i)$ is set to zero if the entity did not cause an event or one if the entity did cause an event. The total number of events, y , in a fixed time interval is then the sum of all $x(i)$ for that entity (Crawford, 1981:10). Crawford then explains:

Suppose that $\Pr\{x(i) = 1\} = p(i)$. If the entities act independently and all the $p(i)$ are equal to some value p , y has a binomial distribution. If n is fairly large and p is small, the Poisson distribution with mean np provides a very good approximation to the distribution of y . (1981:10)

Poisson Distributions. Poisson distributions are the basis for the demand processes of repairable inventory models. This is explained best by Crawford:

the Poisson distribution is a good approximation to an arrival process generated by a collection of entities acting independently of one another, each with a small probability of generating an event in a given short time interval. (1981:10)

A process, denoted by $\{N(t), t \geq 0\}$, is said to be a Poisson process with mean rate λ if the following assumptions are true:

1. $\{N(t), t \geq 0\}$ has stationary independent increments.
2. For any times s and t such that $s < t$, the $N(t) - N(s)$ counts in the interval (s, t) is Poisson distributed with mean $\lambda(t-s)$. That is.

$$P[N(t) - N(s) = k] = \frac{(e^{-\lambda(t-s)}) (\lambda(t-s))^k}{k!} \quad k=0,1,2,\dots \quad (1)$$

(Sherbrooke, 1966:2)

The distribution of the time between arrivals, or demands, is an exponential distribution (Feeney and Sherbrooke, 1966:393).

Compound Poisson Distributions. A compound Poisson distribution is a generalization of the simple Poisson distribution (Feeney and Sherbrooke, 1966:393). The compound Poisson distribution, however, deals with batches of demands rather than a single demand (Feeney and Sherbrooke, 1966:393). From an inventory management perspective, the compound Poisson distribution represents “a series of customers with Poisson arrivals who demand an amount which has an independent discrete distribution” (Feeney and Sherbrooke, 1966:393).

There are three basic properties to the compound Poisson distribution:

1. Any compound Poisson distribution with a positive, discrete compounding distribution has a variance that equals or exceeds its mean.
2. The compound Poisson distributions are the most general class of ‘memoryless’ discrete distributions.
3. The summation of N independent compound Poisson processes with mean customer arrival rates $\lambda_1, \lambda_2, \dots, \lambda_N$ yields a compound Poisson process with mean customer arrival rate $\lambda =$ the sum over all N of λ_i . (Sherbrooke, 1966:7)

Compound Poisson distributions are manifested in other types of distributions. Of those distributions, the negative binomial is used in inventory management models. The probability mass function of the negative binomial is expressed in equation (2).

$$p(x) = \binom{x+n-1}{n-1} p^n (1-p)^x \quad 0 < p < 1, \quad x=0,1,2,\dots \quad (2)$$

The mean of this negative binomial, denoted by M , is $n(1-p)/p$; and the variance, denoted by V , is $n(1-p)/p^2$ (Hadley and Whitin, 1963:101).

Palm's Theorem. Another important foundation of reparable inventory modeling is Palm's Theorem. There is a classical form and a generalized form of this theorem. The classical form is the basis for the reparable inventory modeling under a steady state or peacetime environment. The theorem, as it pertains to reparable inventory modeling and control, is stated below:

If demand for an item is a Poisson process with annual mean m and if the repair time for each failed unit is independently and identically distributed according to any distribution with mean T years, then the steady-state probability distribution for the number of units in repair has a Poisson distribution with mean mT .
(Sherbrooke, 1992:21)

This theorem leads to the assumption of what is known as the "*infinite channel queuing assumption*" (Sherbrooke, 1992:21). This assumption, when used in reparable inventory modeling, translates to "the availability of unlimited repair resources" (Klinger, 1994:12). Although there is not an unlimited supply of repair resources, the theorem is still acceptable because the shape of the repair distribution is not required and the number of units in resupply is still Poisson with mean mT (Sherbrooke, 1992:21).

Aircraft Availability

Now that the foundations for reparable inventory control have been explained, we can now apply them to the AAM. An aircraft is considered operationally available if it is not waiting for a reparable component to be repaired or shipped. In other words, an

available aircraft is one with no reparable unit backorders (Rexroad, 1992:5). This definition highlights the relationship between number of backorders and aircraft availability.

The calculation of aircraft availability is a two step process. First, the number of expected backorders is computed. Then, the probability of that backorder occurring on an aircraft is computed. This probability is known as the aircraft availability rate. In other words, the aircraft availability rate is probability that an aircraft is not waiting for a reparable spare part (King, 1985: 1-1). For a detailed derivation of the equations used in the AAM to compute aircraft availability, see Appendix A. The following sections on the expected backorders calculation and the aircraft availability calculation are taken from Rexroad, 1992.

Expected Backorders Calculation. The first part of the calculation of aircraft availability is to calculate the number of expected backorders. To find this, two variables must be known, the first variable is the number of items due in from supply, x , and the second is the amount of stock on hand, s . These variables, combined with the probability distribution of having 'x' units due in from supply, $p(x)$, can then be placed into equation (3) to calculate the expected backorders (EBO).

$$EBO = \sum_{x>s} (x - s)p(x) \quad (3)$$

The probability distribution, $p(x)$, is a compound Poisson distribution, the negative binomial, with average daily demand, λ , average resupply time, τ , and expected number of items in resupply, $\lambda\tau$, which is used as the mean of the negative binomial distribution.

The average daily demand is also the failure, or demand, rate (failure/demand rate). The average resupply time is a combination of three variables. These variables are: the base repair time, the depot repair time, and the order and shipping time.

Aircraft Availability Calculation. Once the number of expected backorders is found, that number is placed into the second part of the AAM calculations, that of aircraft availability. Along with the expected backorders, many more variables are needed for the calculation of aircraft availability. These are variables such as numbers of aircraft, quantities of components on given aircraft, percentages of aircraft with given components installed, total number of components, flying hours of the aircraft, and flying hours of components. These values are obtained from the Air Force's D041 Data Base and placed into the model. The final equation for aircraft availability, equation (4), is used as derived in Appendix A, to calculate the aircraft availability. In equation (4), $q_{(h,i,n)}$ is the probability that an aircraft of mission designator h is not missing component i with n spares in stock.

$$A = \prod_i q_{(h,i,n)} \quad (4)$$

Variables of the Aircraft Availability Model.

There are many pieces of information which are used for the calculation of aircraft availability. Of those pieces, there are four variables used which are mean values: the order and ship time, the base time to repair, the depot time to repair, and the failure/demand rate of the component. Because the model uses the mean value of these variables, the variation in these values is assumed to be known and adequately accounted for in the design of the model. Unfortunately, "even within the fairly steady state world of peacetime flying activity, none of the...assumptions above are supported by the relevant data." (Crawford, 1988:v)

Order and Ship Time. Although the order and ship time may seem somewhat stable, large variations do occur. However, there is a move in the DOD to improve this variable. In the commercial environment, many companies have prospered by shipping needed items in under two days. The Air Force has reviewed this and is currently utilizing

the abilities of these commercial companies to reduce the Air Force's order and ship time to below two days. This move also has the effect of reducing the variance of the order and ship time to less than a day.

Base Repair Time. Currently in the Air Force, aircraft maintenance is being performed on what is known as a three-level system of maintenance. The three-levels of maintenance in this system are the flight line, base repair, and depot repair. For example, if a part on a aircraft is broken, maintenance personnel will judge if they can repair it. If they cannot, they will remove it and send it to base repair. Base repair will then decide if they can repair it; and if not, base repair will send the item to depot repair. Depot repair will then either repair the item or scrap the item and purchase a new one. Although this system is reliable, it can introduce delays due to the number of steps required in the process.

Under the Air Force's new plan of Lean Logistics, aircraft maintenance is being performed on what is known as a two-level system of maintenance. The two levels of the system are the flight line and depot repair. Under this system, if the maintenance personnel cannot repair an item on the flight line, the item is shipped straight to the depot for repair. This eliminates the need for base repair personnel and reduces the steps in the process of repair. With the move in the Air Force to this Lean Logistics system, base repair time has been greatly reduced. In relation to the AAM, the value of base repair time becomes zero.

Failure/Demand Rate. Failure/demand rate is the number of failures or demands of an item that are experienced on a daily basis. Since a failure of an item immediately creates a demand, the failure rate and the demand rate are the same. Although the reliability of equipment on aircraft is high, each failure of an item will not occur at the same time interval. Because of this, there could be a large variability in the failure/demand rate.

The AAM makes the assumption that the mean failure/demand rate is accurate. However, the variability in the assumptions about the failure/demand rate is both relevant and important (Crawford, 1988:v-vi). Because of the relevance of the variability in the failure/demand rate, “[e]xcessive demand variability substantially reduces the confidence we can put in our requirements and capability assessment models” (Crawford, 1988:vi).

Depot Repair Time. In the Lean Logistics system, base repair time is eliminated and the repair of the reparable item is performed only at the depot. Now the time to perform the maintenance at the depot would be even more variable. With an increase in demand of work at the depot, certain items, those easily repaired, may get repaired first. This would then add to the length of time required to repair an item with a more complex problem. Thus, increasing the variability in the depot repair time increases the need to test the variability in aircraft availability.

Summary

To keep the Air Force in a high state of readiness, the Air Force uses a model that computes the expected percentage of aircraft available at any given time. This model is the Air Force’s AAM. However, aircraft availability has never been examined to find the range of aircraft availability which may arise. This study evaluates the variance of aircraft availability due to changes in the input distributions of depot repair time and failure/demand rates.

Chapter III discusses the methodological approach used to perform the research. This approach will begin with a restatement of the problem followed by the steps used to create, verify, and validate the simulation model. Chapter III will conclude with a description of how the simulation model will be used to test the research question.

III. Methodology

Introduction

This chapter explains the method and the steps that will be used to answer the research question. The chapter is laid out in the order in which the steps are to be performed. These steps are: Problem formulation, Basic simplifications and assumptions, Basic model design, Data gathering and generation, Model coding, Verification, Validation, Experimental design, and Data analysis.

Problem Formulation

Purpose of the Study. The purpose of this study is to investigate the effect of the variance in input distributions on aircraft availability. This test will evaluate the variability of aircraft availability through a simulation of the reparable item pipelines of a system using known means and theoretical distributions for input variables.

Specific Problem. Are there significant effects to expected aircraft availability due to variability in the reparable components' input distributions? In order to answer this question, this research question is broken down into investigative questions which focus on individual variables.

Investigative Questions.

1. Does the variance of the distribution of the number of failures/demands have a significant effect on the variability of aircraft availability?
2. Does the magnitude of mean number of failures/demands have a significant effect on the variability of aircraft availability?
3. Does the variance of the distribution of the depot repair times of the components have a significant effect on the variability of aircraft availability?

4. How much variation in aircraft availability results from the different combinations of the input parameters?

Research Hypothesis. To answer the research question, research hypotheses are developed for each of the investigative questions. Research hypotheses consist of both a null hypothesis and an alternative hypothesis. For the first three investigative questions the null and alternative hypothesis are:

H₀: There are no significant effects on aircraft availability

H_A: There is at least one significant effect on aircraft availability

This test will be performed using an ANOVA test at the 95% level. This ANOVA will indicate if each parameter has a significant effect and also if any combinations of these parameters have a significant effect.

The fourth investigative question does not have a research hypothesis. The fourth investigative question will be answered by computing the range of the aircraft availability from the value of the average variance computed during the simulation runs for each test condition. This range will be computed based on an interval of $\pm 2\sigma$.

Basic Simplifications and Assumptions

The first step that must be performed is to state the simplifications and assumptions behind the model. As discussed in the literature review, in a lean logistics environment, the reparable repair is handled using a two level system of maintenance. In the two level system of maintenance, all failed items are sent to the depot for repair. Therefore, the percentage of base repair is zero and the base repair time is also zero. The next simplification is also due to the lean logistics environment. To try to minimize the number of items in the reparable pipelines, commercial transportation organizations can be utilized and the order and ship time will be reduced to a triangular distribution of no less than one day, most likely time of two days, and no more than three days. A final

simplification in the model is to use items with a quantity per aircraft of only one. For example, if an aircraft had two radios, the quantity per aircraft would be two. By using items with a quantity per aircraft of one, simultaneous failures of the same item cannot take place on the same aircraft. If two failures of an item occur simultaneously, then two aircraft are grounded from the two failures.

The basic assumptions behind the simulation model represent the basic assumptions behind the AAM. The first assumption is that of infinite repair resources at the depot, or, when an item is received at the depot, there are an infinite number of personnel to repair that item. Second, there are sufficient repair parts available for the repair process, or in other words, there is no delay time at the depot due to a lack of repair parts. Assumptions three and four revolve around the failure of the item. The third assumption is that it takes only one failure of any item to ground the aircraft, and the fourth assumption is that a failure of an item can only occur on a non-grounded aircraft. However, simultaneous failures of different parts can occur on the same aircraft. Therefore, one aircraft may have more than one failed component at a time.

Basic Model Design

The basic model to be tested begins with the failure of the reparable item as shown in Figure 1, and results in a grounded aircraft. When an item fails, it is removed from the aircraft until a replacement part is installed. From the failure, two actions take place. One action (top branch in figure) is the return of the part to the depot for repair, and the second action (bottom branch in figure) is the request on the supply system for a new part.

Along the top branch, two further actions take place to return the part to serviceable condition. Once the part is received at the depot, the depot must first repair the part. Once the part is repaired, the part is sent to supply for distribution to maintenance.

The bottom branch has three actions that happen sequentially to provide a serviceable part to maintenance. When the request for the part is placed on the supply system, if the supply system has a part, it is issued. If supply does not have a part, it must wait for the repair system to provide a repaired item for reissue. Once supply receives the serviceable part, it is given to maintenance for installation.

From this basic model, the time for which the aircraft waits for a part is downtime for the aircraft and the aircraft is not available. For the entire system, the average number of missing components during a specified time is the number of aircraft, on average, considered grounded for that time. Thus, the total number of aircraft minus the total number of grounded aircraft is the number available, and the number available divided by the total number of aircraft is the percentage of aircraft available or the aircraft availability for that period.

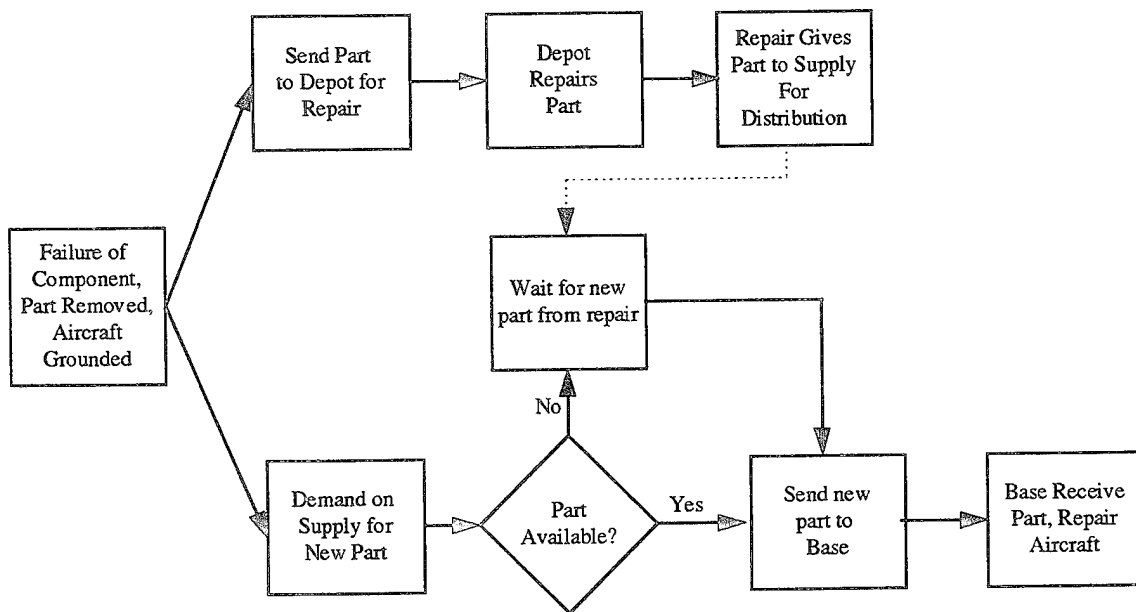


Figure 1. Basic Model

Data Gathering and Generation

There are three variables for which data is required, item failure/demand rate variance, depot repair time variance, and mean failure/demand rate.

Failure/Demand Rate Variance. Failure/demand rate is the number of failures or demands of an item that are experienced on a daily basis. Since a failure of an item immediately creates a demand, the failure rate and the demand rate are the same.

Although the reliability of equipment on aircraft is high, failures do not occur with a constant time between failures. Because of this, there could be a large variability in the failure/demand rate distribution.

For the model, negative binomial distributions for failure/demand rates will be used in the simulations for the items. The negative binomial distribution for the low variance condition will use a variance-to-mean ratio (VMR) of two and the high variance condition will use a VMR of ten. The tables used for the daily demand cumulative density function (CDF) of the part failures, see Appendix E.

Depot Repair Time Variance. As with the failure/demand rates, the depot repair times for the components will be modeled using the same technique. Actual means for the depot repair time for the failed item will be acquired from the Air Force's D041 data base. Distributions for the depot repair times will be applied to the items repair cycle using the mean repair time as the mean of the repair distribution.

For both the low and high conditions a beta distribution will be used to model the repair process. In order to use a Beta distribution, a lower and upper limit must be placed on the repair process. For each item the lower limit will be established at 90% of the mean repair time and the upper limit will be established at 120% of the repair time. For the low condition, a Beta (1,2) distribution will be used to calculate the depot repair time and for the high condition, a Beta (0.5,1) will be used (see Appendix E).

Failure/Demand Rate. The failure/demand rates for the model were calculated using the current Air Force technique of basing the failure/demand rates on the number of flying hours in the quarter. Using this technique, actual repair times from the Air Force's D041 data base were converted from the daily demand rate provided to a demand per 100 flying hours. This value was then used to calculate the daily demand rate for low condition (5000 flying hours) and the high condition (15000 flying hours). The resulting CDF for the different failure/demand rates are found in Appendix E.

Model Coding

The simulation model used to answer the investigative questions consists of two main sections, the control statements and the main network which were coded in SLAM II Simulation Language. The control statements establish initial and operating conditions. The main network executes the simulation and contains the stock and demands for each item, provisioning for the repair, and the resupply of the items. See Appendix B for a detailed description of the model.

Verification

Verification of the model deals with answering the question, "Is the code operating as desired?" Verification was performed in two ways. Because of the relative small size of the simulation model, the first method of verification was a manual desk check of the simulation model before the simulation is executed. This process verified the logic and assumptions placed into the model. The second method was a formal static analysis. This analysis was and will be performed during each compiling of the simulation model. This automated process verifies the syntax of the program and the proper coding of the individual steps in the model.

Validation

Validation of the model is the process of answering the question, "Does the model represent the system to an acceptable level?" Validation of the model was performed using the utilitarian approach. The utilitarian approach to validation looks at the model in three aspects. One aspect of the approach is concerned with the model's face validity. This face validity deals with looking at the model and answering the question, "Does the model look right?" The second aspect of the approach deals with the internal validity of the model. This aspect of internal validity deals with the question, "Is the model structured correctly?" The final aspect is that of predictive validity. Predictive validity looks at the comparison between the inputs and outputs of the model. This validity was explored by running the simulation using the assumed Poisson distributions for the failure/demand rate of the item for both the high and the low demand rates and the constant mean value for the depot repair time. These values for the failure/demand rates and the depot repair times are located in Table 1.

TABLE 1

ACTUAL PARTS DATA

Part Reference Number	Failure/Demand Rate (Low Demand Rate) Parts per Day/MTBF	Failure/Demand Rate (High Demand Rate) Parts per Day/MTBF	Depot Repair Time Days
1	0.030604/32.6755	0.091812/10.89183	13
2	0.025674/38.9502	0.077021/12.9834	28
3	0.053349/18.74442	0.160048/6.24814	13
4	0.017775/56.26005	0.053324/18.75335	34
5	0.019679/50.81465	0.059038/16.93822	31
6	0.019897/50.25927	0.059690/16.75309	139
7	0.018283/54.69462	0.054850/18.23154	139
8	0.015310/65.31882	0.045929/21.77294	64
9	0.019517/51.23826	0.058550/17.07942	139
10	0.040520/24.67927	0.121560/8.226422	15
11	0.021248/47.06234	0.063745/15.68745	16
12	0.015030/66.5329	0.045090/22.17763	67
13	0.100968/9.904103	0.302905/3.301368	48
14	0.037053/26.98824	0.111160/8.99608	55
15	0.264498/3.780752	0.793493/1.260251	37

By using the mean values of the actual data in the simulation model, the mean aircraft availability derived from the simulation is the same as that of the actual run of the AAM. This comparison answers the question of predictive validity.

Experimental Design

The experimental design consists of two approaches. The first approach is the general or strategic approach. The second approach is the specific or tactical approach.

Strategic Approach. The strategic approach of the test utilizes a full factorial design to testing. In the full factorial design, each combination of possibilities of variables, high and low, will be explored. This approach will explore all interactions and effects between the variables. The test matrix for the simulation is shown below in Table 2. For the values of the low and high levels, see the Data Gathering section earlier in this chapter. This design will produce a three factor ANOVA with two levels on each factor. Common random number streams were used in the simulations to ensure that the variances encountered were due to the levels of the factors and not by random effects (Law and Kelton, 1991:613-614). This created a repeated measures design and was evaluated using the SAS system. Each condition was used for ten runs and thus a total of ten observations for each condition was collected.

Tactical Approach. The tactical approach to planning the experiment deals with planning each simulation run. At the start of each simulation run, the supply system will be filled with all available assets. The model will then run for an established number of quarters. This is to allow the pipeline to reach normal or filled conditions. This “warm-up” period was established at 20 quarters by using the Welch graphical technique as described in Law and Kelton (1991:545). These graphical plots are found in Appendix C.

Following this 20 quarter build up, the daily aircraft availability will be collected at the beginning of each day. At the end of the quarter, or 90 days, the average aircraft

availability for the quarter will be reported. This will continue for 25 quarters. The variance of these 25 values will then be computed and used in the ANOVA test.

TABLE 2
EXPERIMENTAL DESIGN MATRIX

Condition Number	Failure/Demand Rate Variance	Failure/Demand Rate	Depot Repair Time Variance
1	low	low	low
2	low	low	high
3	low	high	low
4	low	high	high
5	high	low	low
6	high	low	high
7	high	high	low
8	high	high	high

Note: See Data Gathering Section, Chapter III for values

Data Analysis

There will be two basic types of data analysis. The first type is for the hypothesis tests to answer the first three investigative questions. That hypothesis is:

H_0 : There are no significant effects on aircraft availability

H_A : There is at least one significant effect on aircraft availability

By placing the ten observations of the variance of the aircraft availability into a table, the ANOVA test can be performed on the observed variances the P-values will be provided by the SAS system and the hypothesis will be evaluated.

The second type of analysis will be used to answer the fourth investigative question. Once the observed variances of the conditions are calculated, an interval can be established in which the value for aircraft availability may be in for that condition due to normal randomness in the system.

Summary

This chapter described the techniques used to build, run, and evaluate the information required to answer the investigative questions. The experiment will begin with the building of the simulation networks required to generate the data. Following this, the mean variances for the individual runs is computed and used to input into the SAS system to accomplish the ANOVA test. Once the ANOVA test is completed, the hypothesis can be tested and the range of availabilities can be calculated.

The next chapter presents the data generated, the results of the ANOVA test, and the results of the hypothesis testing. Following Chapter IV, Chapter V presents a summary of the major findings of the study and the conclusions drawn from this research.

IV. Data Analysis and Results

Introduction

This chapter describes the results of the data analysis in response to the investigative questions. First, the results of the validation effort are discussed along with some of the problems experienced. Following that discussion, the data analysis consisting of the SAS system inputs, the resulting ANOVA test results, and the resulting intervals for the conditions is presented.

Validation

In order to test the validation of the simulation networks, the results of the simulation were compared to output from the Air Force's AAM. To perform this validation, two comparisons must be made, one at the low failure/demand rate and one at the high failure/demand rate. Although the AAM normally takes all reparable components on all aircraft in the inventory into account, the input files for the AAM were modified to use the 15 parts used in the simulation and a total of 200 aircraft which was also used in the simulation. When this was accomplished, the value for aircraft availability reported by the AAM in the low failure/demand rate situation was 85.05% and the value for aircraft availability reported by the AAM in the high failure/demand rate situation was 60.67%.

During the validation effort, two problems evolved relating to the calculation of aircraft availability and in the depot repair times in the simulation networks. The first problem came in the calculation of the aircraft availability. At first, aircraft availability was not collected, the number of failed parts was. This number was collected as a time persistent variable and each failure was accepted as generating one downed aircraft. The aircraft availability can then be calculated easily. This method, however, does not account for simultaneous failures of different parts on the same aircraft. This simulation led to

consistently low calculations of aircraft availability by as much as 15%. Once this error was discovered, the simulation was changed to collect the value of aircraft availability on a daily basis and the calculation was used in the same manner in which it is applied in the Air Force's AAM. By calculating the aircraft availability based on each part and multiplying those availabilities together, the calculation is performed in accordance with equation (4) in Chapter II. This brought the simulated aircraft availabilities to within a couple percent of the AAM's value. These values, however, were also consistently low which led to the identification of the other problem.

The other problem, although not as major as the first, was more difficult to find. Because the assumption of two days for the order and ship time was used, two days was also going to be used for the retrograde time to send the part to the depot for repair. This value is included in the depot repair time for both the AAM and the simulations. However, the depot repair times being used in the simulation did not make that adjustment. Once this adjustment was made, the values for aircraft availability fell right in line with those of the AAM. Figures 2 and 3 show the results of the simulation runs, the mean of those runs and the AAM value. As is shown on the figures, the simulated value for aircraft availability were 85.69% and 61.52% for the low and high failure/demand rates respectively. With data this close, no significant difference is found between the simulations and the AAM and thus the simulations are considered valid for this thesis effort.

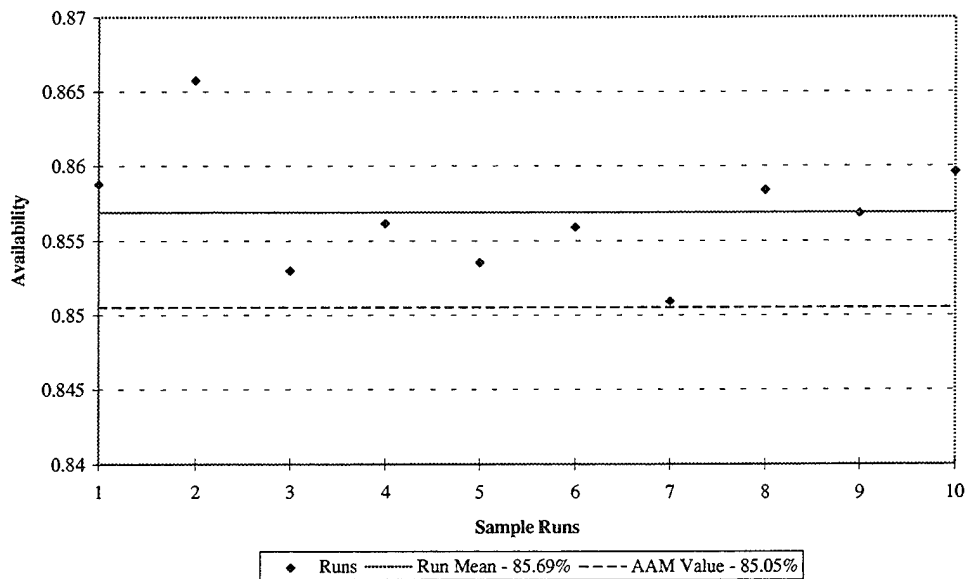


Figure 2. Low Failure/Demand Rate Validation Data

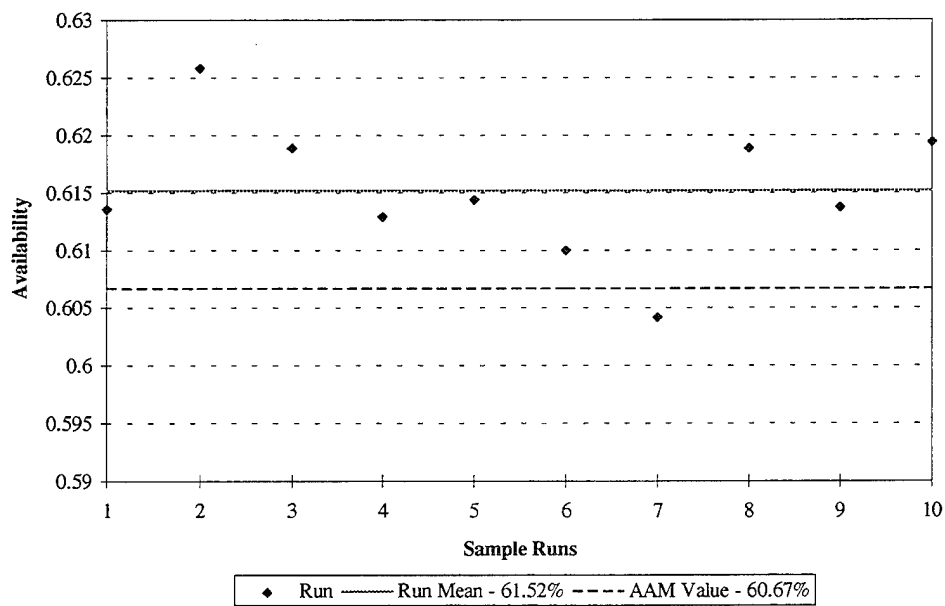


Figure 3. High Failure/Demand Rate Validation Data

Data Analysis

SAS Input. The input to the SAS program was derived from the output of the simulation runs. In order to test if the treatments lead to significant differences in the variance of aircraft availability, the aircraft availability generated from the simulation runs, found in Appendix D, was calculated for each run and the resultant variances (expressed in percentages) are found in Table 3. This table was then to be used as the input data into the SAS program for the ANOVA test. However, one assumption behind the ANOVA test is that the data between treatments must have an equal variance. In Table 4, the variances of the treatments are given and it is obvious from the magnitude of the variances that the data belong to three distinct populations. The division of the treatments into the different populations is also shown in Table 4. The division between population one and the other two is the difference between the low and high failure/demand rate variance. The division between population two and population three is the difference between the low and high failure/demand rate. Because of this separation of the data into different populations, only population one will be tested using the ANOVA test and paired T-tests will be performed within the other two populations. These paired T-tests will be performed at the 99% confidence level.

In order to verify that the data from population one meets the equal variance assumption, Bartlett's test for equality of variances was done as described in Neter, Wasserman and Kutner (1985:618-620). Using the data found in Table 5, a test statistic of 1.194 was calculated. This statistic, when compared to the appropriate χ^2 value of 7.81 at the 95% level, is insufficient to reject the assumption of equal variances. Therefore, the data in population one meets the assumption of equal variances for the ANOVA test.

TABLE 3
VARIANCE TABLE

Run	Condition							
	1	2	3	4	5	6	7	8
1	6.497	6.228	12.104	12.553	10.735	10.494	29.579	29.752
2	2.284	2.374	5.193	5.235	5.043	5.141	11.447	29.752
3	4.688	4.736	7.523	7.423	18.027	17.476	23.748	24.572
4	2.256	2.290	7.060	7.219	9.057	8.933	16.505	16.931
5	7.590	7.084	11.490	11.051	14.777	14.072	30.200	31.218
6	10.086	9.921	15.875	15.246	34.573	34.564	56.524	56.112
7	6.090	6.087	11.479	10.506	19.675	19.421	24.510	24.176
8	3.053	3.022	7.563	7.765	10.589	10.638	16.400	15.955
9	5.924	5.882	7.031	7.515	12.203	12.306	26.832	27.159
10	4.427	4.749	8.528	8.648	10.510	10.631	19.096	18.769

Note: Values are given in %²

TABLE 4
TREATMENT VARIANCES

Treatment	Variance	Population		
		1-Low Variance	2-Intermediate Variance	3-High Variance
1	6.127	X		
2	5.528	X		
3	10.486	X		
4	8.978	X		
5	67.994		X	
6	67.219		X	
7	156.584			X
8	131.504			X

The other assumption behind the ANOVA test is that the data is taken from a normal population. To verify this assumption, a Wilk-Shapiro test was performed on each treatment in population one. In order to satisfy the Bonferoni inequality, each Wilk-Shapiro test was performed at the 99% confidence level to insure an overall level of 95%.

At the 99% confidence level, the Wilk-Shapiro value must be greater than 0.781 and as shown in Table 6 the values of the Wilk-Shapiro test are given and all treatments are acceptable. Therefore, all the treatments in population one meet the assumption of the ANOVA test and the ANOVA was performed on population one.

TABLE 5
BARTLETT'S TEST OF EQUAL VARIANCES

Treatment	s_i^2	df _i	$(df_i)s_i^2$	$\ln(s_i^2)$	$(df_i)\ln(s_i^2)$
1	6.12631	9	55.13679	1.812593	16.31333
2	5.528154	9	49.75339	1.709854	15.38869
3	10.4863	9	94.37671	2.35007	21.15063
4	8.978463	9	80.80617	2.194829	19.75346
Totals		36	280.0731		72.60611
MSE=	7.779807				
Ln(MSE)=	2.051532				

TABLE 6
WILK-SHAPIRO RESULTS

Treatment	Wilk-Shapiro Value
1	0.9533
2	0.9371
3	0.9071
4	0.9279

SAS Results. The values for treatments one through four from the variance table above, Table 3, were used as the input data for the ANOVA test to determine if any of the factors had a significant effect on the variance of aircraft availability. The results of the ANOVA are summed up in Table 7 and the corresponding P-values are presented in Table

8. These P-values produced from the ANOVA test were then used to test for the significance of the effect.

To do this, the P-value is compared to the acceptance level of the test. In order to test all the effects at the 95% level, hypothesis testing was performed to satisfy the Bonferoni inequality and each individual effect was tested at the 99% level (Law and Kelton, 1991:568-572). By testing each effect at the 99% level, the p-value must be less than 0.01 for the effect to be significant and as is shown in Table 8, the failure demand rate has a significant effect on the variance of aircraft availability.

TABLE 7
ANOVA TEST SUMMARY

Source of Variance	df	Sum of Squares	Mean Square	F Value
Failure/Demand Rate	1	167.018	167.018	84.075
Error (Failure/Demand Rate)	9	17.879	1.9865	
Depot Repair Time Variance	1	0.0365	0.0365	0.4624
Error (Depot Repair Time Variance)	9	0.7096	0.0788	
Failure/Demand Rate and Depot Repair Time Variance	1	0.000697	0.000697	0.0120
Error (Failure/Demand Rate and Depot Repair Time Variance)	9	0.5212	0.0579	

TABLE 8
P-VALUE TABLE

Effect	P-Value	Significant?
Failure/Demand Rate	0.00005	Yes
Depot Repair Time Variance	0.9458	No
Failure/Demand Rate and Depot Repair Time Variance	0.9925	No

Paired T-Test Results. The results of the Paired T-tests are found in Table 9. From the table, the p-values from the two tests are both greater than 0.01 and thus no significance difference is found due to the depot repair time variance in either case.

TABLE 9
PAIRED T-TEST RESULTS

Values	Population	
	2-Intermediate Variance	3-High Variance
Mean	0.1512	1.9553
Degrees of Freedom	9	9
T-Statistic	1.66	1.07
P-Value	0.1314	0.3116

Overall Results. With the breakout of population one due to the failure/demand rate variance, the failure/demand rate variance has a significant effect on the variance of aircraft availability. Similarly, because of the difference between population two and three due to the failure/demand rate and the failure/demand rate being significant from the ANOVA, the failure/demand rate has a significant effect on the variance of aircraft availability. With the combination of the ANOVA and the paired t-tests, the depot repair time variance was shown to have no significant effect in all cases. Thus, at the 95% level, the failure/demand rate variance, the failure/demand rate, and the interaction between the two have a significant effect on the variance of aircraft availability.

Availability Intervals. From the simulation runs, variances of aircraft availability were calculated. From these variances an interval can be established for each condition in which the aircraft availability may fall. Therefore, if the system is known to meet the conditions in the simulation, then the value of aircraft availability may fall in a range

around that average aircraft availability found in an expected value model like the Air Force's AAM. In Table 10 below, those ranges are shown with the given condition.

TABLE 10
AIRCRAFT AVAILABILITY RANGES

Condition	Variance	Standard Deviation	Range
1	5.29% ²	2.30%	±4.51%
2	5.24% ²	2.29%	±4.49%
3	9.38% ²	3.06%	±6.00%
4	9.32% ²	3.05%	±5.98%
5	14.52% ²	3.81%	±7.47%
6	14.37% ²	3.79%	±7.43%
7	25.48% ²	5.05%	±9.89%
8	27.44% ²	5.24%	±10.27%

Summary

This chapter presented the results of the simulation runs and the ANOVA test. From the ANOVA test, it was shown that the failure/demand rate variance and the failure/demand rate have significant effects on aircraft availability. Also, because these are significant effects, large variation in aircraft availability can be experienced due strictly to random effects.

The next chapter presents the major findings of this study and the conclusions drawn from those findings. Also included in the next chapter are some recommendations for future research related to this study.

V. Recommendations and Conclusions

This chapter reviews the major issues presented in this study. First, the major findings of the literature review are presented. Then the major results of the ANOVA and the conclusions are presented. This chapter then concludes with some recommendations for future research.

Literature Review Findings

From the literature review, it was found that many assumptions are behind the calculation of aircraft availability. The major assumption found was that of a Poisson failure/demand rate distribution which allows for the calculation of aircraft availability by way of the product rule in equation 4 in Chapter IV.

The other major finding of the literature review is that of the variables used in the availability calculation. Of those variables, the mean values of the order and ship time, the base repair time, the failure/demand rate, and the depot repair time are used in that calculation. Because the mean values are used, that value of aircraft availability calculated does not take into account the possibility of the actual value being other than the mean. In actuality, if the values can be other than the mean, then the actual aircraft availability may not be that calculated value and a range of aircraft availabilities is now possible. It is this possibility of a range of values that led to this study.

Test Results

Failure/Demand Rate Variance. As was shown in Chapter IV, the original ANOVA was reduced to just the treatments where the failure/demand rate variance level was low, which indicates that the failure/demand rate variance has a significant effect on aircraft availability.

Failure/Demand Rate. The ANOVA results clearly indicate that the failure/demand rate has a significant effect on the variance of the possible values of aircraft availability for a low failure/demand rate variance. Also, because of the obvious population difference between population two and three, the failure/demand rate has a significant effect on aircraft availability for a high failure/demand rate variance.

Depot Repair Time Variance. From the ANOVA and also the two paired t-tests, the depot repair time variance was shown to not have a significant effect on aircraft availability. This finding agrees with the statement of Palm's theorem that the repair time can have any distribution.

Aircraft Availabilities. From the aircraft availability simulations it was shown that the variation which may be experienced in actuality may range from the computed value by as much as 10%.

Conclusions

Based on the variables used and the limited number of parts simulated, it is clear that the values generated by the expected value models like the AAM are not complete because the distribution of the input parameters is not taken into account. Therefore, decisions made in the field based on meeting or not meeting an expected value generated by the AAM should be examined carefully to ensure that the difference between the expected value and the actual value is not due merely to random effects in the system.

To look at these findings in a much broader aspect, this situation could occur in many situations. In any capability assessment model which uses the mean values for input parameters, variances in the actual capability will lead to a range of actual values. As before, each decision which is based on meeting a given level generated by a mean value assessment model should be thoroughly examined to ensure that this random effect is taken into account.

Recommended Future Research

This investigation into aircraft availability is a good start, however, it was limited in the number of parts simulated and the number of input parameters examined. In order to find more accurate variances, an increase in the number of parts and including all the input variables in the simulation should be accomplished. This could provide a more accurate estimate of the ranges of aircraft availabilities.

Another aspect of this research which may be explored is that of changing the failure/demand rate variances for the parts independently. Because the failure/demand rate variance has a significant effect on the variance of aircraft availability, there may be some effect on aircraft availability not uncovered in this research.

Finally, a detailed rebuilding of a new aircraft availability model which takes the variance of the parameters into consideration would be very beneficial. From this type of model, capability assessments could be made using a range of values and a most likely value. This would automatically account for the randomness inherent in the system. Thus, if the actual value were outside the range predicted by the new model, it would be quickly noticed and the true cause of the difference could be investigated. Because only values outside the predicted range would be investigated, this would save money by not investigating all the differences except those outside the range.

APPENDIX A: The Aircraft Availability Model Calculations

The following description of the this aircraft availability computation is taken from The Aircraft Availability Model: Conceptual Framework and Mathematics, T.J. O'Malley, June 1983.

Before the description of the mathematics begins, a list of the variables and their meanings is presented. Following the list, the mathematics for the aircraft availability model will be presented ending with the Aircraft Availability formula.

h	MD or Mission Designator, e.g. F-15, F-16, B-1, C-17
$h(k)$	MDS or Mission Designator Subtype, e.g. F-15C, F-15E, F-16A
$k(h)$	Total number of MDS $h(k)$ of a given MD h
i	A reparable component
n	Number of spares in stock
$EBO_{i,n}$	Expected Backorder of component i , with n spares in stock
$a_{h(k),i}$	Quantity of component i on MDS $h(k)$
a	Total number of components on MDS $h(k)$
$b_{h(k),i}$	Percentage of MDS $h(k)$ with component i installed
$P()$	The Probability of what is in the parenthesis
T_i	Total number of component i installed on MD h

The computation begins with calculating the probability of having a backorder for a given reparable part. This probability is found by dividing the number of expected backorders by the total number of components installed and is expressed in the equation:

$$P(\text{Backorder}) = \frac{EBO_{i,n}}{T_i} \quad (A1)$$

Since having a backorder and not having a backorder are mutually exclusive and exhaustive, the probability of not having a backorder is:

$$P(\text{No Backorder}) = 1 - P(\text{Backorder}) = 1 - \frac{EBO_{i,n}}{T_i} \quad (A2)$$

And to apply this to an aircraft, we must use the multiplication rule of probabilities and multiply the probability by itself for each aircraft type. In doing this, the probability an aircraft is not waiting for a spare part(no backorder) is:

$$P(\text{Aircraft not waiting for spare of component } i) = \left(1 - \frac{\text{EBO}_{i,n}}{T_i}\right)^{a_{(h(k),i)}} \quad (\text{A3})$$

This probability can now be expanded to include all aircraft of MDS $h(k)$. To do this, the percentage of aircraft with component i will be brought into the equation. Since those aircraft that do not have the component will never have a backorder for that component, we will add that percentage of aircraft to the percentage of aircraft that do have the component multiplied by the probability that an aircraft will have that component backordered. If we denote $q_{(h(k),i,n)}$ as the probability that any aircraft of a given MDS is not missing component i then we get equation A4.

$$q_{(h(k),i,n)} = (1 - b_{(h(k),i)}) + \left(b_{(h(k),i)} \left(1 - \frac{\text{EBO}_{i,n}}{T_i}\right)^{a_{(h(k),i)}} \right) \quad (\text{A4})$$

Where $1 - b_{(h(k),i)}$ is the percentage of aircraft that do not have the component.

Because not all aircraft are flown the same amount and items tend to break down based on usage, the amount of usage of each component must be taken into account. To do this, the time for each component is based on the flying hour program of the aircraft. In the next set of equations, the flying hours of the components is calculated and what is known as the Use Factor. The use factor is the average hours a component operates on a MDS $h(k)$ divided by the total hours a component operates. To begin a few more variables will be defined:

$F_{h(k)}$	Flying hours for MDS $h(k)$
F_i	Flying hours of component i
IP	Total component flying hours for component i on all MDS $h(k)$
$T_{h(k),i}$	Total number of component I on all MDS $h(k)$

To calculate the amount of flying time on a given component we will take the number of components on a MDS, multiply it by the percentage of MDS with that component, and then multiply that by the flying hours of the MDS. This will give us the flying time of a component on a MDS. To find this for all aircraft, we must sum up all the MDS's. When that is done we get equation A5 below.

$$IP = \sum_{k=1}^{K(h)} a_{(h(k),i,n)} \cdot b_{(h(k),i,n)} \cdot F_{h(k)} \quad (A5)$$

We then need to find the total number of components on all MDS's. This is done by multiplying the number of components on a MDS by the percentage of MDS with that component and then multiplying that by the total number of MDS aircraft. This gives us equation A6.

$$T_{h(k),i} = a_{(h(k),i)} \cdot b_{(h(k),i)} \cdot N_{h(k)} \quad (A6)$$

Using these two calculations, the Use Factor can now be calculated by dividing the flying hours of the MDS by the total number of components on the MDS and then dividing that result by the total component flying hours divided by the total number of components. This is shown in equation A7.

$$U_{h(k),i} = \frac{\left(\frac{F_{h(k)}}{T_{h(k),i}} \right)}{\left(\frac{IP}{T_i} \right)} \quad (A7)$$

Now that the Use Factor is computed, it can be incorporated into the probability equation for an aircraft not missing a component. To do this, the number of expected backorders is weighted with this use factor through multiplication. This yields equation A8.

$$q_{h(k),i,n} = \left(1 - b_{(h(k),i)} \right) + b_{(h(k),i)} \cdot \left[1 - \frac{U_{h(k),i} \cdot EBO_{i,n}}{T_i} \right]^{a_{(h(k),i)}} \quad (A8)$$

We now weight the probability of aircraft MDS $h(k)$ not missing a component by the percentage of aircraft MDS $h(k)$ of MD h . If $N_{(h(k))}$ is the total number of MDS $h(k)$ and $N_{(h)}$ is the total number of MD h , the probability of aircraft MD h not missing a component is:

$$q_{(h,i,n)} = \sum_{k=1}^{K(h)} \left(\frac{N_{(h(k))}}{N_{(h)}} \left(q_{(h(k),i,n)} \right) \right) \quad (A9)$$

Where $q_{(h,i,n)}$ is the probability that an aircraft of MD h is not missing component i with n spares in stock.

To calculate the aircraft availability, we now take each probability of an aircraft of MD h not missing component i and multiply then all together. This produces the final aircraft availability and is shown by the simple equation, A10, below, where A_h is the probability that an aircraft of MD h is not missing component i .

$$A_h = \prod_i q_{(h,i,n)} \quad (A10)$$

APPENDIX B: The Simulation Model

The following is a description of the simulation model, or network, used to answer the investigative questions of the thesis. This description will begin with the listing of the network and then the narrative description.

The Network

```
GEN,MIKE KAPITZKE,VALID LOW,6/6/1944,1,Y,Y,Y/Y,Y,Y/Y/1,72;
LIMITS,15,4,500;
INITIALIZE,4050,Y;
MONTR,SUMRY,1890,90;
MONTR,CLEAR,1800,90;
SEEDS,263546137(3),295296301(7);
ARRAY(1,4)/0.969860,0.999541,0.999995,1.000000;
ARRAY(2,4)/0.974653,0.999676,0.999997,1.000000;
ARRAY(3,4)/0.948049,0.998627,0.999976,1.000000;
ARRAY(4,4)/0.982382,0.999844,0.999999,1.000000;
ARRAY(5,4)/0.980513,0.999809,0.999999,1.000000;
ARRAY(6,4)/0.980300,0.999805,0.999999,1.000000;
ARRAY(7,4)/0.981883,0.999835,0.999999,1.000000;
ARRAY(8,4)/0.984807,0.999884,0.999999,1.000000;
ARRAY(9,4)/0.980673,0.999812,0.999999,1.000000;
ARRAY(10,4)/0.960290,0.999201,0.999989,1.000000;
ARRAY(11,4)/0.978976,0.999777,0.999998,1.000000;
ARRAY(12,4)/0.985082,0.999888,0.999999,1.000000;
ARRAY(13,5)/0.903962,0.995233,0.999841,0.999996,1.000000;
ARRAY(14,4)/0.963625,0.999330,0.999992,1.000000;
ARRAY(15,6)/0.767591,0.970618,0.997468,0.999835,0.999991,1.000000;
ARRAY(16,6)/0,1,2,3,4,5;
NETWORK;
    RESOURCE/1,S1(0),1;
    RESOURCE/2,S2(0),2;
    RESOURCE/3,S3(0),3;
    RESOURCE/4,S4(0),4;
    RESOURCE/5,S5(0),5;
    RESOURCE/6,S6(0),6;
    RESOURCE/7,S7(0),7;
    RESOURCE/8,S8(0),8;
    RESOURCE/9,S9(0),9;
    RESOURCE/10,S10(0),10;
    RESOURCE/11,S11(0),11;
    RESOURCE/12,S12(0),12;
    RESOURCE/13,S13(0),13;
    RESOURCE/14,S14(0),14;
    RESOURCE/15,S15(0),15;
;
COUNT CREATE,1,1800;
ACTIVITY;
ASSIGN,XX(16)=1-XX(1)/200,XX(17)=1-XX(2)/200,XX(18)=1-XX(3)/200,XX(19)=1-
XX(4)/200,XX(20)=1-XX(5)/200;
```

```

ACTIVITY;
ASSIGN,XX(21)=1-XX(6)/200,XX(22)=1-XX(7)/200,XX(23)=1-XX(8)/200,XX(24)=1-
XX(9)/200,XX(25)=1-XX(10)/200;
ACTIVITY;
ASSIGN,XX(26)=1-XX(11)/200,XX(27)=1-XX(12)/200,XX(28)=1-XX(13)/200,XX(29)=
1-XX(14)/200,XX(30)=1-XX(15)/200;
ACTIVITY;
ASSIGN,XX(31)=XX(16)*XX(17)*XX(18)*XX(19)*XX(20),XX(32)=XX(21)*XX(22)*XX(
23)*XX(24)*XX(25),XX(33)=XX(26)*XX(27)*XX(28)*XX(29)*XX(30),XX(34)=XX(31)*
XX(32)*XX(33);
ACTIVITY;
AVAIL COLCT,XX(34),AVAILABILITY;
ACTIVITY;
TERMINATE;

;
D1 CREATE,1,,1;
ACTIVITY;
AD1 ASSIGN,ATRI(4)=DPROBN(1,16,3),1;
ACTIVITY,,ATRI(4).EQ.0.0;
ACTIVITY,,ATRI(4).NE.0.0,ZAAB;
TERMINATE;
ZAAB UNBATCH,4;
ACTIVITY;
SR1 ASSIGN,ATRI(3)=1,ATRI(2)=13;
ACTIVITY,,,DEPOT;

;
D2 CREATE,1,,1;
ACTIVITY;
AD2 ASSIGN,ATRI(4)=DPROBN(2,16,3),1;
ACTIVITY,,ATRI(4).EQ.0.0;
ACTIVITY,,ATRI(4).NE.0.0,ZAAC;
TERMINATE;
ZAAC UNBATCH,4;
ACTIVITY;
SR2 ASSIGN,ATRI(3)=2,ATRI(2)=28;
ACTIVITY,,,DEPOT;

;
D3 CREATE,1,,1;
ACTIVITY;
AD3 ASSIGN,ATRI(4)=DPROBN(3,16,3),1;
ACTIVITY,,ATRI(4).EQ.0.0;
ACTIVITY,,ATRI(4).NE.0.0,ZAAD;
TERMINATE;
ZAAD UNBATCH,4;
ACTIVITY;
SR3 ASSIGN,ATRI(3)=3,ATRI(2)=13;
ACTIVITY,,,DEPOT;

;
D4 CREATE,1,,1;
ACTIVITY;
AD4 ASSIGN,ATRI(4)=DPROBN(4,16,3),1;
ACTIVITY,,ATRI(4).EQ.0.0;
ACTIVITY,,ATRI(4).NE.0.0,ZAAE;
TERMINATE;
ZAAE UNBATCH,4;
ACTIVITY;
SR4 ASSIGN,ATRI(3)=4,ATRI(2)=34;
ACTIVITY,,,DEPOT;

```

```

;
D5      CREATE,1,,1;
        ACTIVITY;
AD5     ASSIGN,ATRIB(4)=DPROBN(5,16,3),1;
        ACTIVITY,,ATRIB(4).EQ.0.0;
        ACTIVITY,,ATRIB(4).NE.0.0,ZAAF;
        TERMINATE;
ZAAF    UNBATCH,4;
        ACTIVITY;
SR5     ASSIGN,ATRIB(3)=5,ATRIB(2)=31;
        ACTIVITY,,,DEPOT;

;
D6      CREATE,1,,1;
        ACTIVITY;
AD6     ASSIGN,ATRIB(4)=DPROBN(6,16,3),1;
        ACTIVITY,,ATRIB(4).EQ.0.0;
        ACTIVITY,,ATRIB(4).NE.0.0,ZAAG;
        TERMINATE;
ZAAG    UNBATCH,4;
        ACTIVITY;
SR6     ASSIGN,ATRIB(3)=6,ATRIB(2)=139;
        ACTIVITY,,,DEPOT;

;
D7      CREATE,1,,1;
        ACTIVITY;
AD7     ASSIGN,ATRIB(4)=DPROBN(7,16,3),1;
        ACTIVITY,,ATRIB(4).EQ.0.0;
        ACTIVITY,,ATRIB(4).NE.0.0,ZAAH;
        TERMINATE;
ZAAH    UNBATCH,4;
        ACTIVITY;
SR7     ASSIGN,ATRIB(3)=7,ATRIB(2)=139;
        ACTIVITY,,,DEPOT;

;
D8      CREATE,1,,1;
        ACTIVITY;
AD8     ASSIGN,ATRIB(4)=DPROBN(8,16,3),1;
        ACTIVITY,,ATRIB(4).EQ.0.0;
        ACTIVITY,,ATRIB(4).NE.0.0,ZAAI;
        TERMINATE;
ZAAI    UNBATCH,4;
        ACTIVITY;
SR8     ASSIGN,ATRIB(3)=8,ATRIB(2)=64;
        ACTIVITY,,,DEPOT;

;
D9      CREATE,1,,1;
        ACTIVITY;
AD9     ASSIGN,ATRIB(4)=DPROBN(9,16,3),1;
        ACTIVITY,,ATRIB(4).EQ.0.0;
        ACTIVITY,,ATRIB(4).NE.0.0,ZAAJ;
        TERMINATE;
ZAAJ    UNBATCH,4;
        ACTIVITY;
SR9     ASSIGN,ATRIB(3)=9,ATRIB(2)=139;
        ACTIVITY,,,DEPOT;

;
D10     CREATE,1,,1;
        ACTIVITY;

```

```

AD10  ASSIGN,ATRI(4)=DPROBN(10,16,3),1;
      ACTIVITY,,ATRI(4).EQ.0.0;
      ACTIVITY,,ATRI(4).NE.0.0,ZAAK;
      TERMINATE;
ZAAK  UNBATCH,4;
      ACTIVITY;
SR10  ASSIGN,ATRI(3)=10,ATRI(2)=15;
      ACTIVITY,,,DEPOT;
;
D11   CREATE,1,,1;
      ACTIVITY;
AD11  ASSIGN,ATRI(4)=DPROBN(11,16,3),1;
      ACTIVITY,,ATRI(4).EQ.0.0;
      ACTIVITY,,ATRI(4).NE.0.0,ZAAL;
      TERMINATE;
ZAAL  UNBATCH,4;
      ACTIVITY;
SR11  ASSIGN,ATRI(3)=11,ATRI(2)=16;
      ACTIVITY,,,DEPOT;
;
D12   CREATE,1,,1;
      ACTIVITY;
AD12  ASSIGN,ATRI(4)=DPROBN(12,16,3),1;
      ACTIVITY,,ATRI(4).EQ.0.0;
      ACTIVITY,,ATRI(4).NE.0.0,ZAAM;
      TERMINATE;
ZAAM  UNBATCH,4;
      ACTIVITY;
SR12  ASSIGN,ATRI(3)=12,ATRI(2)=67;
      ACTIVITY,,,DEPOT;
;
D13   CREATE,1,,1;
      ACTIVITY;
AD13  ASSIGN,ATRI(4)=DPROBN(13,16,3),1;
      ACTIVITY,,ATRI(4).EQ.0.0;
      ACTIVITY,,ATRI(4).NE.0.0,ZAAN;
      TERMINATE;
ZAAN  UNBATCH,4;
      ACTIVITY;
SR13  ASSIGN,ATRI(3)=13,ATRI(2)=48;
      ACTIVITY,,,DEPOT;
;
D14   CREATE,1,,1;
      ACTIVITY;
AD14  ASSIGN,ATRI(4)=DPROBN(14,16,3),1;
      ACTIVITY,,ATRI(4).EQ.0.0;
      ACTIVITY,,ATRI(4).NE.0.0,ZAAO;
      TERMINATE;
ZAAO  UNBATCH,4;
      ACTIVITY;
SR14  ASSIGN,ATRI(3)=14,ATRI(2)=55;
      ACTIVITY,,,DEPOT;
;
D15   CREATE,1,,1;
      ACTIVITY;
AD15  ASSIGN,ATRI(4)=DPROBN(15,16,3),1;
      ACTIVITY,,ATRI(4).EQ.0.0;
      ACTIVITY,,ATRI(4).NE.0.0,ZAAP;

```

```

        TERMINATE;
ZAAP  UNBATCH,4;
        ACTIVITY;
SR15  ASSIGN,ATRI(3)=15,ATRI(2)=37;
        ACTIVITY,,,DEPOT;
;
DEPOT ASSIGN,II=ATRI(3),XX(II)=XX(II)+1;
        ACTIVITY/1,ATRI(2);
        ACTIVITY,,,SUP;
        ALTER,ATRI(3),+1;
        ACTIVITY;
        TERMINATE;
SUP   AWAIT(ATRI(3)=1,15),ATRI(3);
        ACTIVITY,2,,,OST;
        ALTER,ATRI(3),-1;
        ACTIVITY,,,FREE;
;
FREE  FREE,ATRI(3);
        ACTIVITY;
FILED ASSIGN,II=ATRI(3),XX(II)=XX(II)-1;
        ACTIVITY;
        TERMINATE;
        END;
FIN;

```

The Control Statements

The discussion of the network begins with the control statements. The control statements are used in the network to establish initial and operating conditions for the simulation runs. The simulation is set to run for 1800 days and then the statistical array for the variable XX(34) will be cleared and the simulation will run for another 2250 days. Each 90 days after the first 1800 days, the value of XX(34) will be provided and the statistical array will then be cleared for the next 90 days. This provides for 25 quarters of data for testing.

The SEEDS statement is used to change the random number seed for the particular run and a list of those seeds for the ten runs is found in Table 6. The ARRAY statements are used to generate a sample for the failure/demand of the component. These ARRAY statements are used to create a table of the cumulative density functions of the various failure/demand rates and samples are drawn for each part.

TABLE 11
RANDOM NUMBER SEEDS

Observation Run Number	Random Stream 3 Seed	Random Stream 7 Seed
1	263546137	295296301
2	792106907	901460045
3	110084275	342508323
4	659906551	342636611
5	818254439	028117453
6	442880995	084378253
7	420699949	558556941
8	711941873	854753685
9	406321321	743342539
10	069106341	885306059

The Main Network

Immediately following the network statement is the main simulation network. The main network is divided into five major components. Those components are the resources or stock, the availability collection, the demands, the repairs, and the resupplies.

The Resources The resources in the network represent the amount of uninstalled stock in the system. Each repairable item is represented in the network by the numbers one through 15. For each of the 15 RESOURCE statements, the resource number represents the number of the resource, the number of the part, and the number of the file the entities will wait in for that part to get repaired. These resources are used in

the simulation to represent the amount of uninstalled stock in the supply system. The number of units of the resource at the beginning of the simulation runs represents the extra stock in the supply system for the corresponding part. For example, if a part never fails and all aircraft have the part installed, then whatever is left in the supply system, no matter where it is in the supply system, is the amount of extra stock or, in the network, the resource.

The Availability Collection The collection of the aircraft availability data begins on day 1800. At that day, and each day after, the individual availabilities computed from the individual components is calculated using the ASSIGN nodes. Then all the availabilities are multiplied together to compute the system aircraft availability. This availability is then collected and at the end of 90 days, or one quarter, the average availability is reported, the statistical collection is cleared, and the process continues with the next quarter's collection.

The Demands The demands, or failures, for each of the parts is represented in the network by the CREATE nodes. Each CREATE node represents the failure of a reparable item. Following each create node an activity flows into an ASSIGN node. The purpose of this ASSIGN node is to check if on that day a failure for that part will be generated. This is accomplished by taking a random sample from the ARRAY table in the control statements. If there is not to be a failure, the entity is terminated. If there is to be a failure, the entity continues through the system. The next ASSIGN node serves two purposes in the network. The first purpose is to assign to ATRIB(2) of each entity the repair time it will require. The second purpose is to assign to ATRIB(3) of each entity the file in which the entity will wait for the repaired component. The activities from each ASSIGN node lead to the ASSIGN node "DEPOT." For each failure, this ASSIGN node adds the value of one to the part's corresponding global variable (XX(1) through XX(15)). This variable represents the number of grounded aircraft from that part which is

used to calculate the aircraft availability. After this ASSIGN node, the network branches into the repair process and the resupply process.

The Repairs ACTIVITY 1 represents the actual repair of the item. The duration of the repair for the part is established in the demands section of the network in the ASSIGN node and is assigned to ATRIB(2) of each entity. Therefore, the duration of ACTIVITY 1 is specified as ATRIB(2). Once ACTIVITY 1 is completed, the item is considered repaired and the resource is adjusted to indicate the repaired item has been placed in the supply system and is ready for issue. The adjustment of the resource is accomplished in the ALTER node and the resource, indicated by ATRIB(3) of the entity, is altered up by one.

The Resupply Resupply of the item is represented by the AWAIT node in the network. At the AWAIT node, the entity must wait until a resource, indicated by ATRIB(3) of the entity, becomes available. When a resource is available for that entity, the entity enters the shipping ACTIVITY which represents sending the item to the base for installation. This shipment is represented by ACTIVITY 2 and the duration of the shipping process is two days. When the entity completes ACTIVITY 2, it encounters an ALTER node. This ALTER node, in conjunction with the FREE node following it, represent the removal of the repaired item from the supply system. Following this combination of nodes, an ACTIVITY leads to an ASSIGN node where the number of grounded aircraft is decreased by one to represent the item being installed on the aircraft.

APPENDIX C: Welch's Graphical Procedure for Steady State

This appendix shows the results of the Welch's graphical procedure for determining the "warm-up" period for the simulation models. This "warm-up" period is the time required by the simulation to reach a steady state condition before data is collected in the simulation. Not collecting data during this "warm-up" period ensures that the transient effects of the entities filling the system are not present in the collected data.

To perform this test, the simulation was executed for each treatment for 20 quarters. During this time, the number of failures was collected every five days. Using the procedure described in Law and Kelton (1991:545) with a window of 40 observations, the following plots were generated for each of the eight treatments. From these plots, it was determined that a period of 20 quarters for each treatment and all data runs is sufficient for the simulations to achieve steady state.

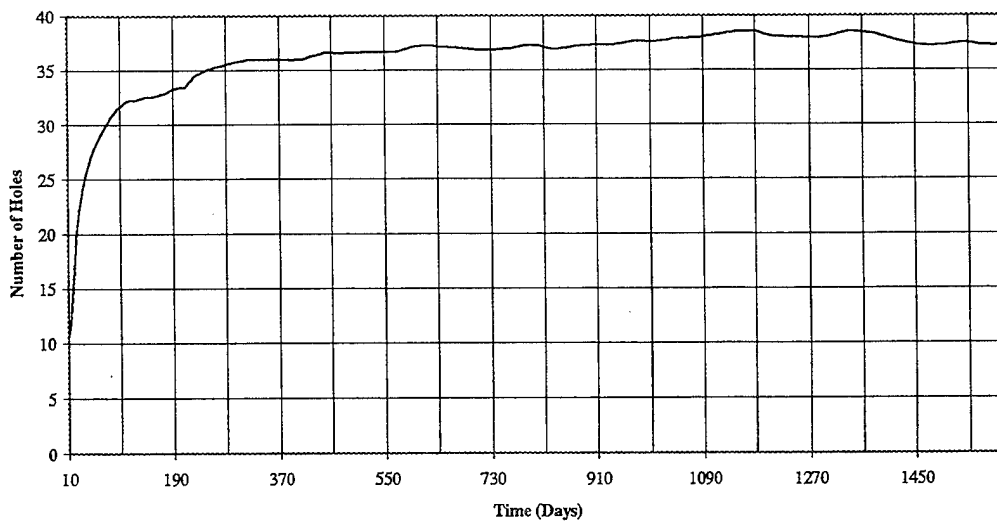


Figure 4. Welch Test for Treatment Number 1

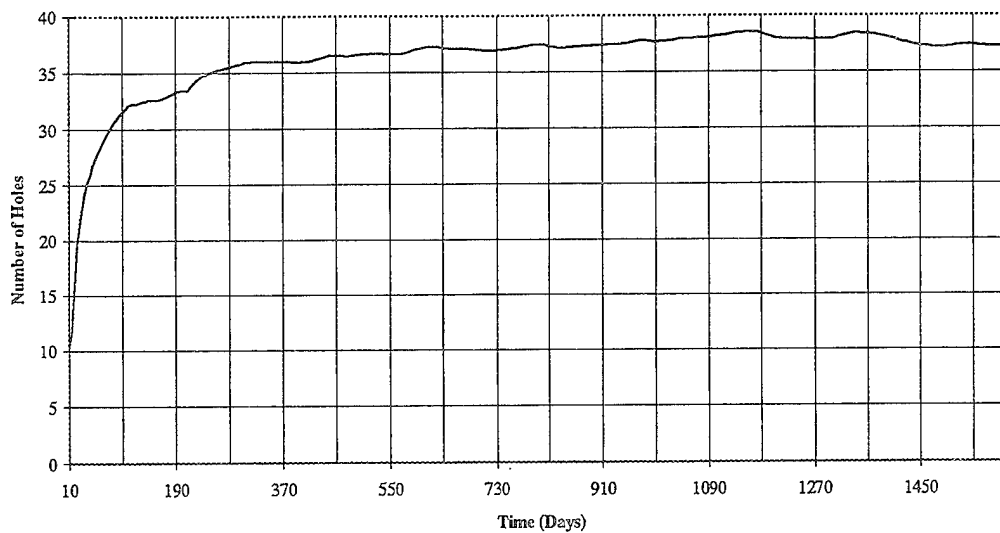


Figure 5. Welch Test for Treatment Number 2

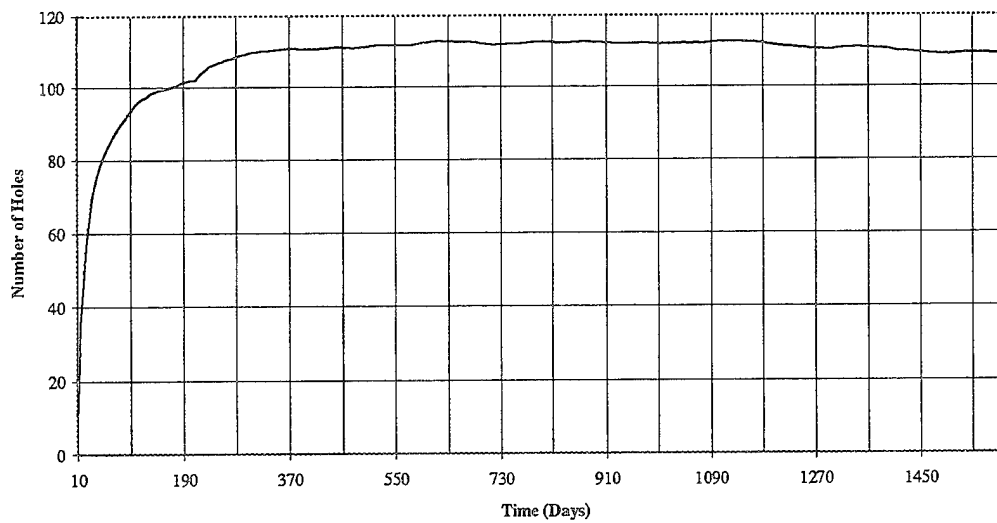


Figure 6. Welch Test for Treatment Number 3

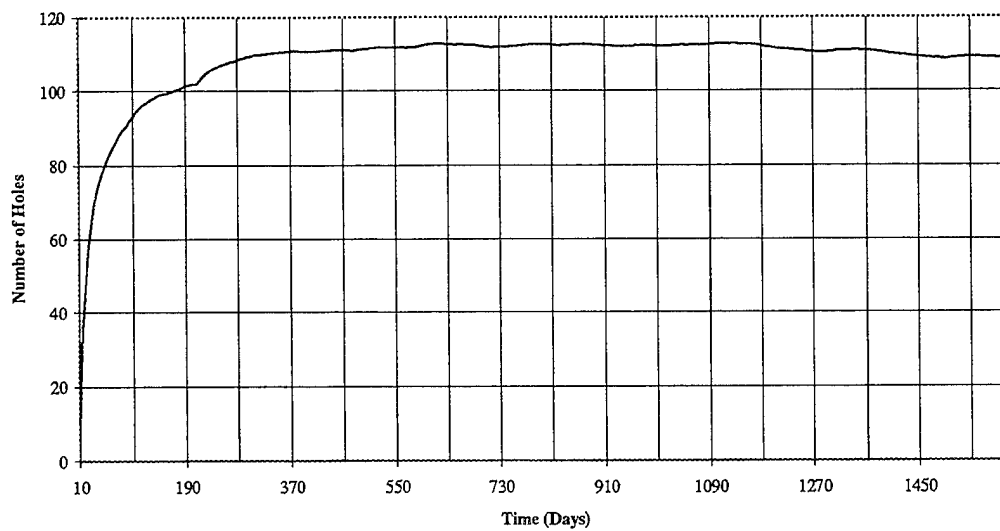


Figure 7. Welch Test for Treatment Number 4

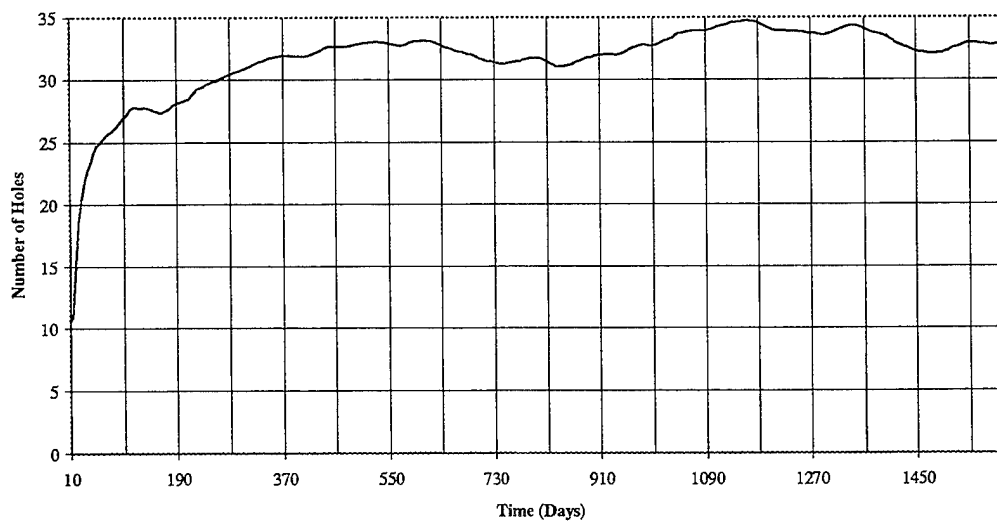


Figure 8. Welch Test for Treatment Number 5

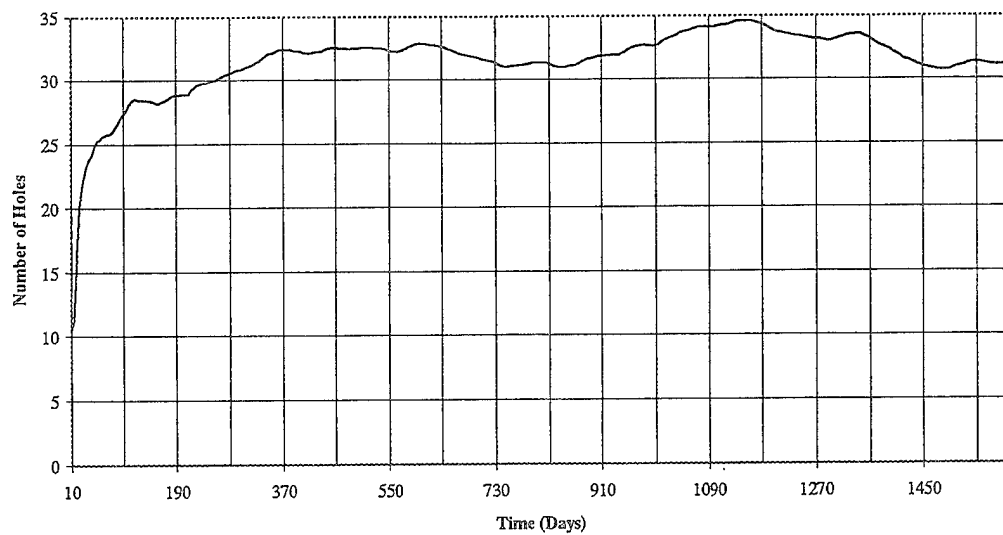


Figure 9. Welch Test for Treatment Number 6

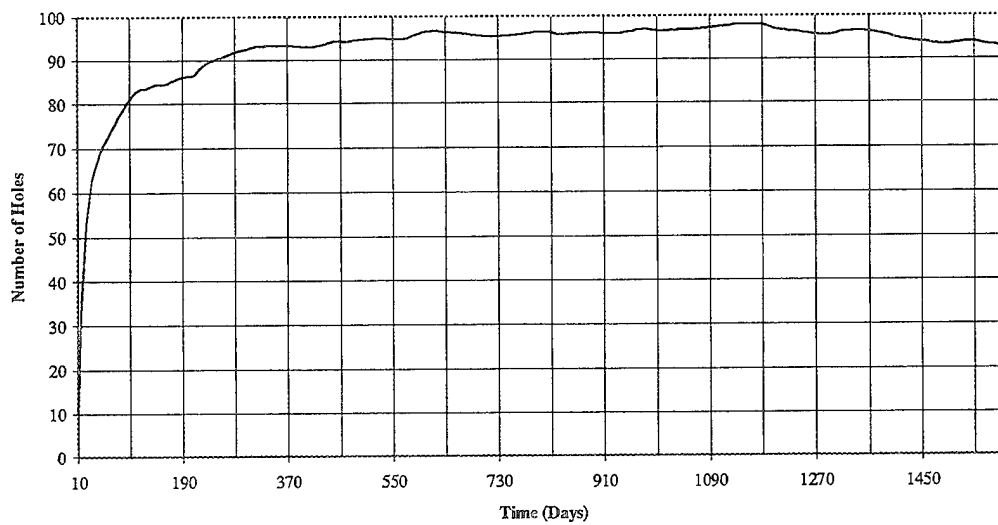


Figure 10. Welch Test for Treatment Number 7

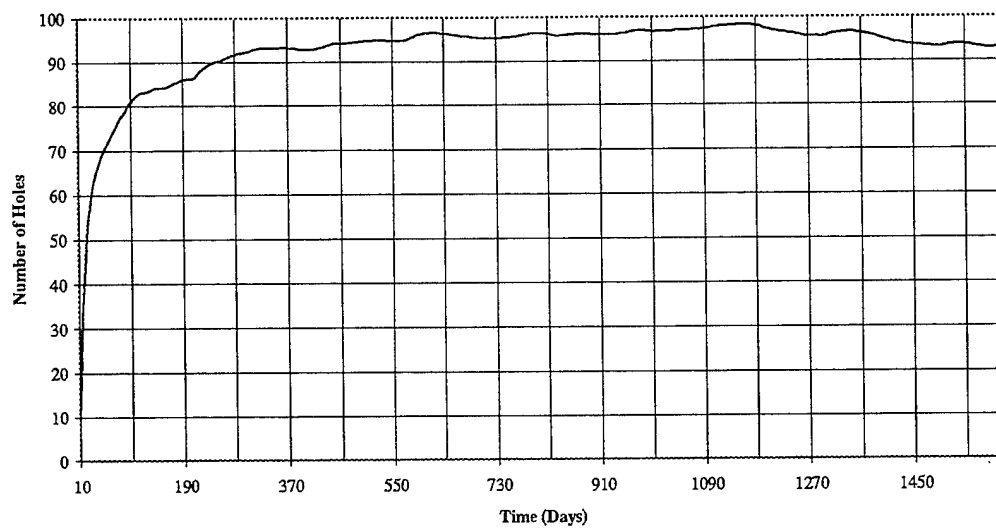


Figure 11. Welch Test for Treatment Number 8

Appendix D: Aircraft Availability Data

This appendix is a summary of the values of aircraft availability generated by the simulation runs. Each table represents a different treatment with the columns representing the different runs. Each treatment represents a different combination of factor levels and each run represents a different execution of the simulation model with different random number seeds. Following these tables is a table which presents the mean aircraft availabilities and the variances for the runs in the treatments.

TABLE 12

TREATMENT NUMBER 1 AIRCRAFT AVAILABILITIES

Quarter	Run Number									
	1	2	3	4	5	6	7	8	9	10
1	87.80%	88.80%	85.40%	85.60%	79.80%	86.00%	88.00%	82.90%	86.70%	84.40%
2	84.70%	84.90%	86.10%	84.20%	84.50%	84.90%	83.40%	88.00%	89.40%	88.10%
3	85.10%	85.10%	87.60%	82.10%	83.30%	85.70%	84.60%	84.40%	88.40%	87.60%
4	84.70%	86.70%	83.80%	84.50%	87.90%	77.50%	87.10%	86.70%	83.00%	82.50%
5	89.10%	88.00%	84.60%	86.30%	88.20%	85.50%	83.60%	82.50%	85.10%	82.50%
6	88.20%	85.30%	82.20%	85.50%	84.50%	85.40%	85.80%	85.90%	84.30%	88.40%
7	83.10%	87.30%	82.40%	83.10%	83.70%	91.50%	80.20%	86.60%	84.00%	86.40%
8	86.30%	85.40%	87.00%	86.70%	88.10%	90.80%	86.30%	86.10%	82.70%	84.50%
9	83.70%	83.90%	84.00%	87.20%	86.90%	88.70%	86.10%	88.40%	87.70%	85.40%
10	85.90%	88.00%	86.20%	85.50%	83.50%	85.90%	87.60%	82.00%	86.50%	84.30%
11	86.50%	84.50%	83.70%	86.50%	87.40%	84.70%	85.10%	83.20%	89.30%	82.80%
12	85.60%	87.50%	88.10%	87.20%	86.20%	85.00%	83.10%	86.50%	81.80%	81.10%
13	87.80%	87.80%	81.50%	87.20%	87.20%	84.90%	82.90%	86.80%	87.20%	87.20%
14	87.70%	87.70%	84.40%	86.40%	80.70%	84.60%	81.30%	85.00%	84.40%	85.90%
15	89.00%	85.10%	85.00%	84.80%	81.70%	88.10%	79.60%	86.10%	87.50%	88.70%
16	84.10%	85.40%	85.20%	84.00%	85.10%	83.10%	83.90%	84.50%	85.90%	86.60%
17	79.40%	86.80%	86.10%	86.40%	87.00%	80.60%	83.70%	85.70%	80.50%	87.20%
18	80.00%	89.20%	89.30%	87.30%	81.90%	82.30%	81.20%	88.30%	82.70%	88.60%
19	87.30%	84.70%	84.10%	85.40%	82.90%	83.60%	84.00%	84.70%	84.50%	85.40%
20	86.00%	87.80%	85.30%	87.30%	86.50%	87.90%	87.30%	86.10%	89.40%	85.10%
21	83.40%	86.60%	86.00%	86.10%	87.00%	87.60%	88.50%	84.70%	86.00%	85.80%
22	85.30%	86.10%	84.00%	85.60%	87.00%	87.90%	83.30%	87.40%	85.80%	85.10%
23	86.90%	88.20%	79.70%	86.50%	80.30%	88.60%	85.90%	86.50%	86.00%	85.60%
24	89.60%	88.50%	85.30%	87.20%	82.60%	81.40%	84.00%	84.20%	87.30%	85.40%
25	86.60%	87.10%	82.10%	82.70%	89.30%	82.60%	87.80%	86.50%	87.90%	88.90%

TABLE 13

TREATMENT NUMBER 2 AIRCRAFT AVAILABILITIES

Quarter	Run Number									
	1	2	3	4	5	6	7	8	9	10
1	88.00%	88.90%	85.10%	85.50%	80.20%	85.90%	88.10%	82.80%	86.70%	84.30%
2	85.00%	84.70%	85.50%	84.00%	84.20%	84.80%	83.60%	88.20%	89.40%	87.80%
3	85.20%	84.70%	87.50%	81.90%	83.70%	85.80%	84.30%	84.20%	88.20%	87.60%
4	84.70%	86.50%	84.00%	84.90%	87.70%	77.60%	87.30%	86.30%	83.10%	82.70%
5	88.90%	88.40%	84.40%	86.60%	87.90%	85.40%	83.70%	82.70%	85.30%	81.90%
6	88.20%	85.50%	82.20%	85.60%	84.60%	85.40%	85.90%	85.60%	84.20%	88.50%
7	83.00%	87.20%	82.50%	83.40%	83.60%	91.20%	80.10%	86.90%	84.20%	86.60%
8	85.90%	85.70%	87.10%	86.90%	87.90%	90.50%	85.80%	86.30%	82.80%	84.80%
9	84.00%	83.80%	84.30%	86.70%	87.20%	88.80%	86.50%	88.60%	87.60%	85.40%
10	86.00%	87.50%	86.30%	85.30%	83.90%	85.90%	87.90%	82.10%	86.40%	84.10%
11	86.60%	85.10%	84.20%	86.80%	87.00%	84.80%	85.10%	83.60%	89.40%	82.50%
12	86.20%	87.60%	88.10%	87.60%	86.00%	84.70%	83.60%	86.30%	81.60%	81.10%
13	88.10%	87.90%	81.30%	87.00%	86.70%	85.10%	83.10%	86.80%	87.50%	87.10%
14	87.50%	87.80%	84.40%	86.10%	80.60%	84.80%	81.00%	85.30%	84.80%	85.70%
15	89.20%	85.20%	85.20%	85.10%	81.50%	87.80%	80.00%	86.30%	87.60%	88.70%
16	84.20%	85.10%	85.10%	83.80%	84.80%	82.90%	84.00%	84.30%	85.90%	86.90%
17	79.50%	86.80%	86.00%	86.30%	86.60%	80.40%	83.90%	85.50%	80.50%	87.20%
18	80.50%	89.10%	89.80%	87.00%	82.00%	81.90%	81.30%	88.10%	82.60%	88.60%
19	87.10%	84.80%	84.30%	85.90%	82.40%	84.00%	84.20%	84.60%	85.00%	85.40%
20	86.10%	87.80%	85.20%	87.50%	87.00%	87.70%	87.60%	86.50%	89.40%	84.70%
21	83.20%	86.40%	86.20%	86.30%	86.70%	87.70%	88.60%	85.10%	86.00%	85.90%
22	85.10%	85.70%	84.10%	85.50%	87.00%	88.20%	83.20%	87.40%	85.70%	85.10%
23	87.10%	88.60%	79.90%	86.20%	80.60%	88.30%	85.90%	86.60%	85.90%	85.70%
24	89.50%	88.50%	85.10%	86.90%	82.70%	81.30%	84.10%	84.10%	87.30%	85.20%
25	86.60%	87.10%	82.00%	82.50%	89.40%	82.40%	87.50%	86.40%	87.90%	89.20%

TABLE 14

TREATMENT NUMBER 3 AIRCRAFT AVAILABILITIES

Quarter	1	2	3	4	5	6	7	8	9	10
1	65.30%	64.00%	62.50%	61.30%	56.10%	63.20%	64.10%	59.80%	63.10%	60.90%
2	61.80%	58.20%	62.40%	59.10%	61.40%	60.20%	60.00%	64.00%	65.10%	65.30%
3	61.50%	60.80%	63.30%	55.60%	60.00%	60.70%	60.10%	59.30%	62.50%	64.60%
4	58.50%	62.30%	61.30%	59.20%	64.00%	54.50%	64.00%	59.50%	59.00%	58.50%
5	65.30%	65.40%	60.10%	60.90%	62.30%	61.70%	60.20%	57.90%	59.60%	56.70%
6	61.40%	61.00%	57.40%	59.50%	57.30%	59.80%	60.70%	63.00%	60.80%	63.10%
7	55.90%	64.20%	59.80%	56.30%	56.90%	68.40%	52.90%	66.30%	60.00%	62.10%
8	59.50%	63.50%	62.60%	63.90%	63.90%	66.80%	61.80%	61.90%	59.90%	61.50%
9	59.70%	62.00%	59.50%	64.10%	61.60%	65.30%	60.50%	66.00%	64.10%	61.30%
10	63.90%	66.70%	62.70%	61.30%	59.50%	62.80%	64.40%	55.90%	62.80%	62.30%
11	66.40%	62.60%	58.80%	62.40%	63.50%	61.80%	63.60%	58.10%	65.90%	55.60%
12	62.20%	62.50%	65.70%	62.90%	64.40%	57.90%	63.60%	63.60%	56.20%	56.20%
13	65.70%	64.00%	56.80%	62.80%	64.70%	59.70%	59.70%	62.40%	61.90%	64.30%
14	65.50%	63.10%	61.40%	63.00%	54.70%	59.50%	55.90%	63.50%	61.70%	63.30%
15	65.70%	61.60%	64.30%	59.00%	58.40%	64.80%	54.80%	59.40%	66.50%	68.50%
16	61.00%	62.20%	62.80%	60.90%	59.50%	60.20%	59.60%	61.10%	62.10%	64.50%
17	54.80%	63.90%	62.70%	64.00%	64.20%	55.90%	57.70%	63.60%	57.60%	62.70%
18	55.00%	68.20%	65.60%	62.80%	59.30%	55.50%	57.10%	64.60%	58.00%	63.70%
19	64.30%	63.40%	59.70%	61.40%	60.10%	58.60%	60.80%	58.50%	59.60%	63.00%
20	64.80%	65.00%	61.60%	65.00%	62.60%	64.50%	66.20%	62.20%	65.00%	61.70%
21	59.80%	63.50%	61.70%	65.20%	60.70%	65.60%	64.20%	61.30%	63.00%	60.80%
22	58.80%	62.10%	61.80%	63.00%	63.00%	67.10%	56.80%	61.40%	62.10%	62.70%
23	62.30%	68.40%	54.50%	62.10%	56.50%	64.80%	61.30%	63.00%	63.50%	63.30%
24	64.30%	65.40%	58.40%	62.50%	59.70%	58.80%	60.60%	61.30%	62.70%	60.70%
25	58.60%	65.30%	57.40%	56.10%	69.70%	54.50%	65.10%	66.40%	64.30%	63.90%

TABLE 15

TREATMENT NUMBER 4 AIRCRAFT AVAILABILITIES

Quarter	Run Number									
	1	2	3	4	5	6	7	8	9	10
1	65.50%	63.80%	61.80%	61.00%	56.40%	63.30%	64.10%	59.20%	62.90%	61.00%
2	61.30%	57.60%	62.40%	59.30%	61.50%	59.90%	59.70%	63.80%	65.00%	65.60%
3	61.90%	60.80%	63.20%	55.70%	60.00%	60.00%	60.20%	59.00%	62.50%	64.60%
4	58.80%	62.20%	61.10%	59.30%	64.10%	54.20%	63.50%	59.50%	59.30%	58.30%
5	65.50%	65.20%	60.30%	60.90%	62.60%	62.00%	59.90%	57.90%	60.30%	56.50%
6	61.30%	61.20%	57.90%	59.10%	57.70%	59.90%	60.90%	63.00%	61.00%	62.80%
7	55.60%	64.30%	59.40%	56.50%	56.60%	68.30%	53.10%	66.10%	60.00%	61.70%
8	59.60%	63.50%	62.60%	64.10%	63.80%	66.80%	61.80%	62.10%	59.60%	61.80%
9	59.60%	62.30%	59.30%	64.20%	61.80%	65.60%	60.70%	65.80%	64.10%	61.20%
10	63.80%	66.80%	62.50%	61.10%	59.10%	62.80%	64.20%	55.50%	63.20%	62.40%
11	66.10%	62.60%	59.30%	62.80%	62.80%	62.20%	63.30%	58.00%	66.10%	55.70%
12	62.20%	62.40%	66.10%	62.80%	64.30%	57.60%	63.20%	63.50%	55.80%	56.00%
13	66.30%	64.10%	56.30%	63.10%	64.50%	60.00%	59.40%	62.70%	62.00%	64.10%
14	65.60%	63.30%	61.20%	62.90%	54.70%	59.90%	56.00%	63.40%	62.10%	63.50%
15	65.90%	61.70%	64.30%	59.30%	57.80%	64.10%	54.90%	59.70%	66.70%	67.90%
16	60.90%	62.40%	62.30%	60.90%	59.30%	60.10%	60.40%	61.00%	62.10%	64.60%
17	55.10%	63.60%	62.50%	64.40%	63.70%	56.10%	58.20%	63.60%	57.40%	62.70%
18	54.80%	67.80%	66.10%	63.10%	59.40%	55.90%	57.20%	64.80%	57.50%	64.00%
19	63.60%	63.20%	60.30%	61.00%	60.10%	58.30%	60.80%	58.10%	59.40%	63.00%
20	64.50%	64.70%	61.40%	65.00%	62.40%	64.10%	66.10%	62.10%	64.60%	61.70%
21	59.60%	63.10%	61.20%	65.00%	60.70%	65.20%	64.10%	61.50%	62.90%	60.80%
22	58.40%	62.10%	61.30%	62.80%	63.20%	66.90%	57.20%	61.40%	62.20%	63.40%
23	62.40%	68.60%	54.70%	62.40%	56.60%	64.60%	61.60%	62.90%	63.60%	63.30%
24	64.20%	65.40%	58.20%	62.40%	59.60%	58.50%	60.90%	61.40%	63.10%	60.60%
25	57.90%	64.90%	57.80%	55.80%	69.40%	55.00%	64.80%	66.10%	64.60%	64.20%

TABLE 16

TREATMENT NUMBER 5 AIRCRAFT AVAILABILITIES

Quarter	Run Number									
	1	2	3	4	5	6	7	8	9	10
1	94.50%	93.80%	87.50%	89.30%	78.50%	90.90%	89.60%	83.30%	91.70%	83.60%
2	86.10%	86.70%	92.00%	87.80%	85.40%	90.70%	83.60%	93.70%	91.20%	86.30%
3	85.50%	87.50%	91.50%	83.80%	82.20%	90.20%	83.50%	82.90%	91.10%	85.70%
4	85.40%	89.10%	85.40%	89.20%	86.30%	76.40%	90.00%	89.70%	82.60%	82.10%
5	92.60%	89.30%	87.50%	89.80%	90.80%	87.20%	85.20%	82.60%	86.60%	83.00%
6	90.00%	88.70%	79.40%	81.20%	86.60%	86.90%	88.50%	82.30%	85.70%	90.70%
7	86.60%	89.60%	82.60%	87.50%	85.80%	99.50%	81.10%	87.90%	85.10%	90.50%
8	88.20%	90.00%	88.70%	92.60%	90.30%	97.50%	86.80%	88.60%	86.60%	87.00%
9	86.30%	86.00%	86.70%	88.30%	87.80%	89.80%	86.80%	92.40%	89.90%	86.10%
10	90.00%	89.40%	89.00%	84.40%	86.90%	88.50%	93.20%	85.70%	89.50%	84.10%
11	87.90%	84.20%	83.30%	88.30%	88.20%	86.60%	82.50%	89.20%	93.50%	86.90%
12	86.00%	92.10%	91.30%	89.50%	88.20%	88.60%	83.50%	85.20%	81.50%	82.30%
13	93.00%	89.70%	76.20%	90.50%	90.40%	84.80%	85.30%	88.90%	91.20%	87.60%
14	91.10%	89.90%	82.50%	86.80%	80.20%	86.10%	81.80%	85.70%	87.80%	88.00%
15	93.00%	86.60%	90.10%	86.20%	84.80%	87.70%	81.50%	87.60%	91.20%	93.20%
16	87.10%	88.50%	90.80%	81.30%	86.70%	81.00%	84.80%	85.00%	85.40%	91.40%
17	81.10%	90.20%	87.20%	87.80%	89.90%	73.70%	79.20%	87.70%	79.80%	90.60%
18	81.60%	94.50%	92.90%	89.20%	84.40%	78.20%	75.10%	91.40%	85.60%	90.40%
19	90.10%	89.10%	82.50%	87.60%	81.00%	81.30%	85.50%	86.90%	86.90%	81.70%
20	90.50%	91.20%	85.50%	89.50%	90.00%	86.90%	90.30%	89.90%	93.10%	87.80%
21	88.10%	89.50%	87.90%	83.50%	90.00%	88.50%	93.10%	90.20%	89.90%	87.40%
22	87.60%	87.90%	83.70%	82.60%	89.30%	90.80%	86.50%	94.00%	89.20%	88.20%
23	88.30%	89.40%	82.40%	88.20%	78.10%	92.50%	87.80%	88.50%	87.30%	90.00%
24	89.90%	90.40%	90.00%	88.40%	84.10%	82.20%	86.60%	87.60%	86.80%	83.80%
25	88.80%	90.70%	82.80%	83.20%	90.80%	87.10%	93.20%	89.50%	88.10%	89.90%

TABLE 17

TREATMENT NUMBER 6 AIRCRAFT AVAILABILITIES

Quarter	Run Number									
	1	2	3	4	5	6	7	8	9	10
1	94.30%	93.70%	87.60%	89.30%	79.20%	90.90%	89.50%	83.50%	91.40%	83.60%
2	86.10%	86.60%	91.90%	87.90%	85.70%	90.90%	83.50%	93.50%	91.10%	85.90%
3	85.50%	87.40%	91.60%	83.80%	82.20%	90.20%	83.40%	82.30%	90.50%	85.40%
4	84.70%	89.10%	85.40%	89.00%	86.00%	76.40%	89.50%	89.40%	82.60%	82.00%
5	92.80%	88.90%	87.40%	89.30%	91.00%	87.10%	85.30%	82.70%	86.50%	82.80%
6	90.00%	88.80%	79.20%	81.50%	86.60%	87.00%	88.90%	82.30%	85.30%	90.50%
7	86.60%	89.80%	82.50%	87.90%	85.40%	99.50%	81.10%	87.90%	85.30%	90.60%
8	88.10%	90.00%	88.80%	92.70%	90.50%	97.50%	86.60%	88.40%	86.60%	87.00%
9	86.30%	85.80%	86.70%	88.40%	87.70%	90.00%	86.70%	92.40%	89.70%	86.10%
10	89.80%	89.60%	88.70%	84.50%	86.70%	88.20%	93.10%	85.70%	89.90%	83.70%
11	87.80%	84.20%	83.50%	88.60%	88.10%	86.80%	82.40%	89.30%	93.70%	86.70%
12	85.90%	92.10%	90.70%	89.30%	88.30%	88.50%	83.30%	85.10%	81.20%	82.40%
13	92.80%	89.60%	76.20%	90.60%	90.70%	84.90%	85.60%	88.90%	91.30%	88.40%
14	91.20%	89.70%	83.20%	87.00%	80.40%	85.90%	82.00%	85.80%	87.50%	87.90%
15	92.90%	86.70%	90.30%	86.10%	85.30%	87.60%	82.00%	87.60%	91.00%	93.20%
16	87.00%	88.40%	90.70%	81.10%	86.40%	80.90%	84.90%	84.90%	85.20%	91.50%
17	81.20%	90.30%	87.30%	87.80%	90.00%	73.70%	78.90%	87.90%	79.80%	90.40%
18	82.00%	94.60%	92.70%	89.30%	84.60%	78.40%	75.20%	91.40%	85.80%	90.10%
19	90.00%	89.10%	82.60%	87.70%	80.50%	81.30%	85.80%	86.80%	87.40%	81.90%
20	90.30%	91.10%	85.70%	89.70%	89.40%	87.20%	90.10%	89.90%	93.40%	87.30%
21	88.00%	89.50%	87.60%	83.60%	90.00%	88.50%	93.10%	90.30%	89.80%	87.30%
22	87.80%	87.70%	83.40%	82.60%	89.10%	90.60%	86.70%	94.00%	88.90%	88.20%
23	88.30%	89.60%	82.40%	88.00%	78.60%	92.60%	87.80%	88.60%	87.10%	90.20%
24	90.00%	90.10%	89.80%	88.20%	84.30%	82.10%	86.60%	87.40%	87.10%	83.80%
25	88.70%	90.80%	82.90%	83.30%	90.80%	86.50%	93.30%	89.30%	88.20%	89.90%

TABLE 18

TREATMENT NUMBER 7 AIRCRAFT AVAILABILITIES

Quarter	Run Number									
	1	2	3	4	5	6	7	8	9	10
1	73.40%	73.70%	65.50%	65.50%	57.90%	67.50%	70.10%	63.90%	70.00%	66.60%
2	66.00%	69.40%	68.00%	62.80%	66.30%	64.60%	61.10%	73.70%	74.50%	69.40%
3	65.60%	65.20%	71.00%	56.10%	61.30%	65.70%	63.90%	66.90%	70.70%	67.00%
4	63.20%	67.10%	66.40%	66.10%	70.60%	50.80%	70.30%	70.60%	62.00%	59.40%
5	75.10%	71.50%	64.60%	68.20%	71.20%	63.90%	61.60%	63.60%	67.30%	58.10%
6	70.40%	64.60%	59.10%	63.60%	63.80%	67.60%	65.00%	67.00%	61.50%	75.30%
7	59.70%	71.20%	61.90%	59.80%	61.50%	85.40%	57.60%	68.60%	66.40%	70.70%
8	64.90%	72.80%	73.00%	71.10%	70.90%	82.00%	66.90%	66.10%	60.80%	65.40%
9	63.70%	66.60%	65.30%	69.20%	66.40%	71.40%	68.40%	72.10%	71.80%	67.20%
10	67.60%	70.70%	69.00%	65.50%	61.50%	68.00%	74.40%	56.30%	69.40%	65.60%
11	68.90%	65.70%	63.10%	68.50%	67.90%	65.50%	65.60%	61.20%	76.70%	62.60%
12	67.40%	72.10%	72.40%	73.00%	70.40%	66.80%	61.80%	65.60%	56.80%	58.90%
13	72.10%	70.20%	56.70%	69.10%	70.70%	64.50%	61.10%	65.30%	69.80%	70.60%
14	71.50%	68.70%	64.30%	65.40%	53.80%	62.00%	60.50%	63.40%	62.30%	63.80%
15	74.20%	65.10%	69.40%	64.80%	57.70%	67.20%	57.30%	66.50%	69.10%	71.10%
16	60.90%	64.60%	68.00%	61.40%	63.70%	60.10%	65.70%	62.40%	65.80%	68.70%
17	52.20%	67.30%	67.10%	68.70%	65.10%	55.40%	61.70%	67.70%	58.90%	68.10%
18	57.00%	75.30%	77.00%	71.10%	60.80%	60.70%	56.10%	71.50%	60.30%	71.10%
19	72.00%	65.50%	64.20%	66.50%	59.90%	59.30%	61.90%	64.50%	62.80%	66.70%
20	68.20%	69.30%	68.10%	69.50%	68.60%	69.20%	68.90%	69.60%	72.80%	67.40%
21	63.70%	66.40%	68.20%	66.80%	68.20%	69.80%	71.30%	69.80%	68.90%	65.00%
22	65.30%	68.20%	63.60%	66.80%	71.20%	71.80%	61.20%	73.10%	68.80%	67.70%
23	66.70%	76.20%	55.30%	68.70%	57.50%	74.10%	65.70%	69.40%	67.90%	70.70%
24	70.10%	71.60%	67.90%	68.50%	62.10%	60.70%	59.70%	63.30%	68.70%	64.50%
25	67.10%	71.10%	64.20%	58.60%	75.30%	58.50%	72.30%	67.80%	73.00%	74.60%

TABLE 19

TREATMENT NUMBER 8 AIRCRAFT AVAILABILITIES

Quarter	Run Number									
	1	2	3	4	5	6	7	8	9	10
1	73.40%	73.40%	65.30%	66.20%	57.70%	67.30%	69.90%	64.50%	69.40%	66.80%
2	65.70%	65.70%	68.20%	62.80%	66.00%	64.30%	60.90%	73.70%	74.20%	69.20%
3	65.20%	65.20%	71.20%	56.10%	61.20%	65.80%	63.80%	66.60%	71.20%	66.60%
4	63.30%	63.30%	65.80%	66.00%	70.60%	51.30%	70.00%	70.70%	62.00%	59.70%
5	75.00%	75.00%	64.40%	67.90%	71.40%	63.80%	61.90%	63.50%	66.60%	58.00%
6	70.40%	70.40%	58.50%	63.70%	63.60%	67.60%	64.40%	66.80%	61.60%	75.20%
7	60.00%	60.00%	61.70%	59.80%	61.80%	85.40%	57.50%	68.40%	66.50%	70.80%
8	65.20%	65.20%	73.20%	71.20%	70.60%	82.00%	67.10%	65.90%	60.90%	65.30%
9	63.70%	63.70%	65.40%	69.10%	66.50%	71.10%	68.40%	72.30%	72.10%	67.10%
10	67.80%	67.80%	68.90%	65.40%	61.50%	68.40%	74.10%	56.40%	69.50%	65.80%
11	69.10%	69.10%	63.40%	69.00%	67.50%	65.40%	65.50%	61.50%	77.00%	62.70%
12	67.30%	67.30%	72.20%	73.10%	70.50%	66.70%	62.00%	65.20%	56.70%	58.70%
13	71.90%	71.90%	56.70%	69.50%	70.40%	64.60%	62.10%	65.50%	69.50%	70.70%
14	71.80%	71.80%	63.80%	65.20%	53.70%	62.30%	60.40%	62.80%	62.50%	64.00%
15	74.10%	74.10%	69.30%	64.70%	56.80%	67.20%	57.30%	66.20%	68.90%	71.20%
16	61.00%	61.00%	68.40%	61.60%	63.70%	60.30%	65.80%	62.40%	66.00%	68.70%
17	51.90%	51.90%	67.20%	68.70%	65.20%	55.60%	61.30%	67.10%	59.00%	68.10%
18	56.90%	56.90%	77.10%	71.30%	60.70%	60.20%	56.10%	71.10%	59.40%	70.90%
19	71.80%	71.80%	63.80%	66.80%	59.40%	59.70%	62.10%	64.50%	62.90%	66.60%
20	68.00%	68.00%	67.80%	69.60%	68.70%	69.30%	69.00%	69.10%	72.90%	67.30%
21	63.80%	63.80%	68.50%	66.60%	67.60%	69.70%	71.80%	70.00%	68.40%	65.30%
22	65.20%	65.20%	63.70%	66.80%	71.20%	71.80%	61.80%	72.90%	68.80%	67.10%
23	67.00%	67.00%	55.20%	68.90%	57.00%	74.80%	65.90%	69.40%	68.20%	70.80%
24	70.50%	70.50%	67.70%	68.80%	62.70%	61.00%	59.60%	63.70%	68.30%	64.60%
25	66.90%	66.90%	64.40%	58.50%	75.50%	58.10%	72.30%	67.90%	72.80%	74.40%

TABLE 20

MEAN AIRCRAFT AVAILABILITIES
AND VARIANCES

Treatment		Run Number										Average
		1	2	3	4	5	6	7	8	9	10	
1	Mean	85.75%	86.66%	84.76%	85.65%	84.93%	85.39%	84.57%	85.59%	85.76%	85.74%	85.48%
	Var.	6.496767	2.284233	4.68233	2.255933	7.5896	10.08577	6.0896	3.052767	5.924167	4.4275	5.289457
2	Mean	85.82%	86.66%	84.79%	85.65%	84.88%	85.33%	84.65%	85.62%	85.80%	85.71%	85.49%
	Var.	6.228067	2.374233	4.735767	2.2901	7.0844	9.921433	6.086767	3.0219	5.8825	4.7491	5.237427
3	Mean	61.68%	63.57%	60.99%	61.37%	60.96%	61.30%	60.63%	61.76%	61.88%	62.05%	61.62%
	Var.	12.10417	5.192933	7.523267	7.0596	11.49	15.8754	11.47877	7.563333	7.030833	8.5276	9.38459
4	Mean	61.62%	63.50%	60.94%	61.40%	60.88%	61.25%	60.65%	61.68%	61.92%	62.06%	61.59%
	Var.	12.55307	5.234567	7.4225	7.218733	11.05057	15.24593	10.50593	7.764733	7.515	8.647567	9.31586
5	Mean	88.37%	89.36%	86.38%	87.06%	86.27%	86.94%	85.80%	87.86%	87.89%	87.13%	87.31%
	Var.	10.7346	5.0425	18.0269	9.056667	14.77727	34.57257	19.675	10.58923	12.20327	10.50977	14.51878
6	Mean	88.32%	89.33%	86.35%	87.09%	86.30%	86.93%	85.81%	87.81%	87.85%	87.07%	87.29%
	Var.	10.49357	5.141267	17.47593	8.932767	14.0725	34.56377	19.4211	10.63777	12.30593	10.63127	14.36759
7	Mean	66.68%	69.20%	66.13%	66.21%	64.97%	66.10%	64.40%	66.80%	67.08%	67.05%	66.46%
	Var.	29.5794	11.44707	23.7481	16.50527	30.20043	56.52417	24.5104	16.4004	26.83167	19.09593	25.48428
8	Mean	66.68%	66.68%	66.07%	66.29%	64.86%	66.15%	64.44%	66.72%	67.01%	67.02%	66.19%
	Var.	29.7519	29.7519	24.5721	16.93077	31.2175	56.11177	24.17583	15.95523	27.15943	18.7694	27.43958

Appendix E: Simulation Input Tables

Summary

This appendix presents the failure/demand rate tables used in the array statements and the tables used to calculate the depot repair time from the beta distributions in the simulation networks. Also, the Poisson failure/demand rate tables for the validation runs are presented.

TABLE 21
LOW FAILURE/DEMAND RATE AND
LOW FAILURE/DEMAND RATE VARIANCE

Part	P(0)	P(1)	P(2)	P(3)	P(4)	P(5)	P(6)	P(7)	P(8)	P(9)	P(10)
1	0.979010	0.993991	0.997851	0.999157	0.999652	0.999852	0.999935	0.999971	0.999987	0.999994	1.000000
2	0.982362	0.994972	0.998206	0.999297	0.999710	0.999877	0.999946	0.999976	0.999989	0.999995	1.000000
3	0.963697	0.989403	0.996172	0.998489	0.999373	0.999731	0.999882	0.999948	0.999976	0.999989	1.000000
4	0.987755	0.996534	0.998767	0.999518	0.999802	0.999916	0.999963	0.999984	0.999993	0.999997	1.000000
5	0.986452	0.996158	0.998633	0.999466	0.999780	0.999906	0.999959	0.999982	0.999992	0.999996	1.000000
6	0.986303	0.996115	0.998617	0.999459	0.999777	0.999905	0.999959	0.999982	0.999992	0.999996	1.000000
7	0.987407	0.996433	0.998731	0.999504	0.999796	0.999913	0.999962	0.999983	0.999992	0.999997	1.000000
8	0.989444	0.997018	0.998941	0.999587	0.999830	0.999928	0.999968	0.999986	0.999994	0.999997	1.000000
9	0.986563	0.996190	0.998644	0.999470	0.999782	0.999907	0.999960	0.999982	0.999992	0.999996	1.000000
10	0.972305	0.992003	0.997128	0.998870	0.999533	0.999800	0.999913	0.999961	0.999982	0.999992	1.000000
11	0.985380	0.995849	0.998521	0.999422	0.999762	0.999899	0.999956	0.999980	0.999991	0.999996	1.000000
12	0.989636	0.997073	0.998960	0.999594	0.999833	0.999929	0.999969	0.999986	0.999994	0.999997	1.000000
13	0.932407	0.979479	0.992435	0.996972	0.998730	0.999451	0.999758	0.999891	0.999951	0.999977	1.000000
14	0.974644	0.992701	0.997382	0.998971	0.999575	0.999818	0.999921	0.999965	0.999984	0.999993	1.000000
15	0.832489	0.942584	0.977388	0.990524	0.995884	0.998170	0.999172	0.999621	0.999825	0.999918	1.000000

TABLE 22
LOW FAILURE/DEMAND RATE AND
HIGH FAILURE/DEMAND RATE VARIANCE

Part	P(0)	P(1)	P(2)	P(3)	P(4)	P(5)	P(6)	P(7)	P(8)	P(9)	P(10)
1	0.992201	0.995237	0.996608	0.997432	0.997989	0.998391	0.998692	0.998924	0.999107	0.999254	1.000000
2	0.993453	0.996004	0.997155	0.997846	0.998314	0.998650	0.998903	0.999098	0.999252	0.999374	1.000000
3	0.986444	0.991706	0.994089	0.995522	0.996492	0.997191	0.997716	0.998121	0.998441	0.998696	1.000000
4	0.995463	0.997232	0.998030	0.998509	0.998833	0.999066	0.999241	0.999376	0.999482	0.999567	1.000000
5	0.994978	0.996936	0.997819	0.998349	0.998708	0.998966	0.999159	0.999309	0.999427	0.999521	1.000000
6	0.994922	0.996902	0.997795	0.998331	0.998693	0.998954	0.999150	0.999301	0.999420	0.999515	1.000000
7	0.995333	0.997153	0.997974	0.998466	0.998799	0.999039	0.999219	0.999358	0.999467	0.999555	1.000000
8	0.996091	0.997616	0.998303	0.998716	0.998995	0.999196	0.999346	0.999463	0.999554	0.999627	1.000000
9	0.995019	0.996961	0.997837	0.998363	0.998718	0.998974	0.999166	0.999315	0.999431	0.999525	1.000000
10	0.989687	0.993697	0.995510	0.996600	0.997337	0.997868	0.998267	0.998574	0.998817	0.999011	1.000000
11	0.994578	0.996692	0.997645	0.998218	0.998604	0.998883	0.999092	0.999254	0.999381	0.999483	1.000000
12	0.996162	0.997659	0.998334	0.998739	0.999013	0.999210	0.999358	0.999472	0.999562	0.999634	1.000000
13	0.974499	0.984338	0.988816	0.991517	0.993347	0.994669	0.995662	0.996430	0.997036	0.997521	1.000000
14	0.990565	0.994235	0.995894	0.996891	0.997565	0.998051	0.998415	0.998697	0.998919	0.999096	1.000000
15	0.934569	0.959288	0.970739	0.977710	0.982462	0.985908	0.988508	0.990523	0.992117	0.993397	1.000000

TABLE 23
HIGH FAILURE/DEMAND RATE AND
LOW FAILURE/DEMAND RATE VARIANCE

Part	P(0)	P(1)	P(2)	P(3)	P(4)	P(5)	P(6)	P(7)	P(8)	P(9)	P(10)
1	0.938344	0.981419	0.993177	0.997276	0.998860	0.999508	0.999783	0.999903	0.999956	0.999980	1.000000
2	0.948013	0.984522	0.994352	0.997755	0.999063	0.999597	0.999823	0.999921	0.999964	0.999984	1.000000
3	0.894996	0.966616	0.987387	0.994865	0.997819	0.999048	0.999576	0.999808	0.999913	0.999960	1.000000
4	0.963713	0.989408	0.996174	0.998490	0.999373	0.999732	0.999882	0.999948	0.999976	0.999989	1.000000
5	0.959904	0.988239	0.995741	0.998316	0.999300	0.999700	0.999868	0.999941	0.999974	0.999988	1.000000
6	0.959470	0.988106	0.995692	0.998296	0.999292	0.999696	0.999867	0.999941	0.999973	0.999988	1.000000
7	0.962695	0.989096	0.996059	0.998443	0.999354	0.999723	0.999879	0.999946	0.999976	0.999989	1.000000
8	0.968666	0.990911	0.996727	0.998711	0.999466	0.999772	0.999900	0.999956	0.999980	0.999991	1.000000
9	0.960229	0.988339	0.995779	0.998331	0.999307	0.999703	0.999870	0.999942	0.999974	0.999988	1.000000
10	0.919193	0.975062	0.990727	0.996266	0.998427	0.999318	0.999698	0.999864	0.999938	0.999972	1.000000
11	0.956777	0.987272	0.995382	0.998171	0.999239	0.999674	0.999857	0.999936	0.999971	0.999987	1.000000
12	0.969229	0.991081	0.996790	0.998736	0.999476	0.999776	0.999902	0.999956	0.999980	0.999991	1.000000
13	0.810619	0.933389	0.973378	0.988727	0.995064	0.997790	0.998995	0.999538	0.999785	0.999900	1.000000
14	0.925844	0.977302	0.991596	0.996626	0.998582	0.999386	0.999729	0.999878	0.999945	0.999975	1.000000
15	0.576946	0.805847	0.908480	0.956264	0.978923	0.989784	0.995028	0.997572	0.998812	0.999417	1.000000

TABLE 24
HIGH FAILURE/DEMAND RATE AND
HIGH FAILURE/DEMAND RATE VARIANCE

Part	p(0)	p(1)	p(2)	p(3)	p(4)	p(5)	p(6)	p(7)	p(8)	p(9)	p(10)
1	0.976784	0.985752	0.989829	0.992288	0.993953	0.995155	0.996058	0.996756	0.997307	0.997748	1.000000
2	0.980488	0.988039	0.991467	0.993532	0.994930	0.995939	0.996697	0.997282	0.997744	0.998113	1.000000
3	0.959880	0.975243	0.982279	0.986538	0.989430	0.991521	0.993096	0.994314	0.995275	0.996046	1.000000
4	0.986450	0.991710	0.994091	0.995524	0.996493	0.997192	0.997717	0.998122	0.998441	0.998697	1.000000
5	0.985009	0.990824	0.993458	0.995044	0.996117	0.996890	0.997471	0.997920	0.998273	0.998557	1.000000
6	0.984845	0.990723	0.993386	0.994989	0.996074	0.996856	0.997443	0.997897	0.998254	0.998540	1.000000
7	0.986065	0.991474	0.993922	0.995396	0.996393	0.997111	0.997651	0.998068	0.998397	0.998660	1.000000
8	0.988318	0.992857	0.994911	0.996146	0.996981	0.997583	0.998035	0.998383	0.998658	0.998879	1.000000
9	0.985132	0.990900	0.993512	0.995085	0.996149	0.996916	0.997492	0.997937	0.998288	0.998569	1.000000
10	0.969379	0.981162	0.986537	0.989783	0.991984	0.993574	0.994770	0.995695	0.996424	0.997009	1.000000
11	0.983824	0.990095	0.992937	0.994648	0.995806	0.996641	0.997269	0.997753	0.998135	0.998441	1.000000
12	0.988530	0.992988	0.995003	0.996216	0.997036	0.997627	0.998070	0.998413	0.998683	0.998899	1.000000
13	0.925431	0.953462	0.966501	0.974456	0.979886	0.983828	0.986805	0.989114	0.990942	0.992409	1.000000
14	0.971961	0.982766	0.987687	0.990659	0.992673	0.994127	0.995221	0.996066	0.996733	0.997268	1.000000
15	0.816271	0.881041	0.912757	0.932626	0.946432	0.956591	0.964345	0.970414	0.975254	0.979168	1.000000

TABLE 25
POISSON FAILURE/DEMAND RATE
FOR LOW VALIDATION RUNS

Part	P(0)	P(1)	P(2)	P(3)	P(4)	P(5)
1	0.969860	0.999541	0.999995	1.000000		
2	0.974653	0.999676	0.999997	1.000000		
3	0.948049	0.998627	0.999976	1.000000		
4	0.982382	0.999844	0.999999	1.000000		
5	0.980513	0.999809	0.999999	1.000000		
6	0.980300	0.999805	0.999999	1.000000		
7	0.981883	0.999835	0.999999	1.000000		
8	0.984807	0.999884	0.999999	1.000000		
9	0.980673	0.999812	0.999999	1.000000		
10	0.960290	0.999201	0.999989	1.000000		
11	0.978976	0.999777	0.999998	1.000000		
12	0.985082	0.999888	0.999999	1.000000		
13	0.903962	0.995233	0.999841	0.999996	1.000000	
14	0.963625	0.999330	0.999992	1.000000		
15	0.767591	0.970618	0.997468	0.999835	0.999991	1.000000

TABLE 26

POISSON FAILURE/DEMAND RATE
FOR HIGH VALIDATION RUNS

Part	P(0)	P(1)	P(2)	P(3)	P(4)	P(5)
1	0.912277	0.996035	0.999880	0.999997	1.000000	
2	0.925870	0.997182	0.999928	0.999999	1.000000	
3	0.852103	0.988480	0.999394	0.999976	0.999999	1.000000
4	0.948073	0.998628	0.999976	1.000000		
5	0.942671	0.998324	0.999967	1.000000		
6	0.942056	0.998288	0.999966	0.999999	1.000000	
7	0.946627	0.998550	0.999974	1.000000		
8	0.955110	0.998977	0.999984	1.000000		
9	0.943131	0.998351	0.999968	1.000000		
10	0.885538	0.993184	0.999727	0.999992	1.000000	
11	0.938244	0.998053	0.999959	0.999999	1.000000	
12	0.955911	0.999013	0.999985	1.000000		
13	0.738669	0.962416	0.996303	0.999724	0.999983	1.000000
14	0.894796	0.994261	0.999789	0.999994	1.000000	
15	0.452262	0.811129	0.953508	0.991167	0.998638	1.000000

TABLE 27**DEPOT REPAIR TIME DISTRIBUTION INTERVALS
FOR LOW DEPOT REPAIR TIME VARIANCE, BETA (1,2)**

Part	Minimum	Mode	Average	Maximum
1	11.7	11.7	13	15.6
2	25.2	25.2	28	33.6
3	11.7	11.7	13	15.6
4	30.6	30.6	34	40.8
5	27.9	27.9	31	37.2
6	125.1	125.1	139	166.8
7	125.1	125.1	139	166.8
8	57.6	57.6	64	76.8
9	125.1	125.1	139	166.8
10	13.5	13.5	15	18
11	14.4	14.4	16	19.2
12	60.3	60.3	67	80.4
13	43.2	43.2	48	57.6
14	49.5	49.5	55	66
15	33.3	33.3	37	44.4

Note: Repair times given in days

TABLE 28

DEPOT REPAIR TIME DISTRIBUTION INTERVALS
FOR HIGH DEPOT REPAIR TIME VARIANCE, BETA(0.5,1)

Part	Minimum	Mode	Average	Maximum
1	11.7	11.7	13	15.6
2	25.2	25.2	28	33.6
3	11.7	11.7	13	15.6
4	30.6	30.6	34	40.8
5	27.9	27.9	31	37.2
6	125.1	125.1	139	166.8
7	125.1	125.1	139	166.8
8	57.6	57.6	64	76.8
9	125.1	125.1	139	166.8
10	13.5	13.5	15	18
11	14.4	14.4	16	19.2
12	60.3	60.3	67	80.4
13	43.2	43.2	48	57.6
14	49.5	49.5	55	66
15	33.3	33.3	37	44.4

Note: Repair times given in days

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Vita

Capt Michael S. Kapitzke was born on 24 April 1964 in South Ruislip, England. He graduated from Friendly High School in 1982 and began his undergraduate studies at Auburn University. He was selected as an ROTC Distinguished Graduate and received his regular commission and graduated with a Bachelor of Aerospace Engineering in June 1986. His first assignment was at Edwards AFB as a Flight Test Engineer where he performed In-flight Icing and Aerial Refueling tests. His next assignment was at the National Air Intelligence Center where he was a Space Launch Vehicle Analyst. In May 1994, he entered the School of Logistics and Acquisition Management, Air Force Institute of Technology.

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